THE JUNE SCIENTIFIC MONTHLY

EDITED BY J. McKEEN CATTELL

THE ORIGIN OF THE GAMMA-RAYS. LORD RUTHERFORD ... 483
THE MASTER KEY OF SCIENCE. HENRY NORRIS RUSSELL ... 487
THE CADUCEUS. STUART L. TYSON ... 492
TIME-CHANGES OF THE EARTH'S MAGNETIC FIELD. J. A. FLEMING ... 499
THE CLINICAL APPLICATION OF BLOW-FLY LARVAE. DR. EDWARD F. ROBERTS ... 531
A SIMPLIFIED CALENDAR. DR. EDMUND BURKE DELABARRE ... 537
ENVIRONMENT AND HEREDITY. DR. A. S. PEARSE ... 541
POPULAR USAGE OF THE TERMS "INSTINCT" AND "INSTINCTIVE." DR. RICHARD STEPHEN UHRBROCK ... 544
SCIENCE SERVICE RADIO TALKS:
THE SURVEY OF THE CONTINENTAL SHELF. COMMANDER G. T. RUDE ... 547
METALS IN THE USE OF MAN. PROFESSOR C. H. DESCH ... 550
ODDITIES OF THE OCEAN. LIEUTENANT-COMMANDER R. R. LUKENS ... 552
"GENES"—THE UNITS OF HEREDITY. DR. FRANK F. BUNKER ... 556
THE PROGRESS OF SCIENCE:
Wilhelm Ostwald; the Boyden Station of Harvard College Observatory in South Africa; the U. S. Forest Products Laboratory ... 567

THE SCIENCE PRESS
LANCASTER, PA.—GRAND CENTRAL TERMINAL, N. Y. CITY—GARRISON, N. Y.

Yearly Subscription $5.00 Single Copies 50 cents

NEW BOOKS OF SCIENTIFIC INTEREST

Plants: What They Are and What They Do. A. C. SEWARD. x + 141 pp. Illustrated. $1.50. Macmillan.

This book describes in language free from technical terms the aspects of plant life which should interest persons without previous botanical knowledge. The author attempts to interest laymen in some of the fundamental principles of biology.

How to Understand Chemistry. A. FREDERICK COLLINS. xii + 322 pp. 31 figures. $2.00. D. Appleton and Company.

The author explains the signs, words and phrases used in chemistry, tells of matter and its make-up, discusses the common elements and attempts to explain the entire field of present-day chemistry in its application to everyday life.

Nature Rambles—Summer. OLIVER P. MEDSGER. viii + 160 pp. Illustrated. $2.00. Frederick Warne and Company.

This volume is an introduction to country-lore. The author desires to make the study of nature alluring by describing the wonders of nature to be observed in rambles through woods, mountains and on the seashore.

Animal Biology. LORANDE L. WOODRUFF. xii + 513 pp. Illustrated. $3.50. The Macmillan Company.

A volume designed especially for use in college courses in animal biology and general zoology. A synoptic review of representative forms from each of the chief phyla of the animal kingdom is included.

Imhotep to Harvey: Backgrounds of Medical History. C. N. B. CAMAC. 324 pp. $3.75. Paul B. Hoeber.

This volume traces the art of healing to ancient times, bringing the history of medicine within the reach of medical undergraduates and those with whom medicine may become an avocation.

The Harvey Lectures. THE HARVEY SOCIETY OF NEW YORK. 186 pp. Illustrated. Williams and Wilkins.

This volume, the 26th in the series, covers a wide range of topics. The object of these lectures in the field of medical science is to bring forward unsettled problems and discuss them freely. Each subject is treated comprehensively.

The Remaking of Man in Africa. J. H. OLDHAM and B. D. GIBSON. 185 pp. $1.25. Oxford University Press.

The purpose of this book is to consider the contribution of Christian education to the right solution of whether the new influences to which the African is subject will lead to his advancement or his undoing.

Practical Mathematics. GLENN M. HOBBS, MARGARET MACLENNAN and JAMES MCKINNEY. ii + 448 pp. $2.00. Illustrated. American Technical Society.

A book presenting the principles of arithmetic, equations, formulas, mensuration, graphs, logarithms, etc., by a simple step-by-step method, for vocational and home-study students.

Elementary Bacteriology. Second edition. DR. JOSEPH E. GREAVES and ETHELYN O. GREAVES. 535 pp. Illustrated. $3.50. W. B. Saunders Company.

The fundamentals of the science are fully presented. The discovery of bacteria and early ideas and theories are followed by chapters on classification and composition of bacteria, and a discussion of their activity in the world of man.

Medical Entomology. WILLIAM A. RILEY and OSKAR A. JOHANNSEN. xi + 476 pp. $4.50. Illustrated. The McGraw-Hill Book Company.

This text-book is a survey of insects and their allied forms which affect the health of man and animals. The authors direct the attention of the reader to the pioneer work as well as the current literature.

Profitable Practice in Industrial Research. Edited by MALCOLM ROSS. xii + 269 pp. $4.00. Harper and Brothers.

A presentation of the accumulated experience of the past twenty-five years in American industrial research. The directors of numerous research laboratories point out the value in research programs.

The Quest for Vocational Adjustment in the Profession of Education. WALTER E. HAGER. ix + 86 pp. $1.50. Teachers College, Columbia University.

The author discusses the question of whether a person who has been engaged for a number of years in one particular field of educational work should try to obtain a better vocational adjustment in another field.

The Concepts of Sociology. EARLE E. EUBANK. xvii + 570 pp. $4.80. D. C. Heath and Company.

A treatise covering the main elements of sociological theory. It emphasizes the nature and functions of concepts in the development of human knowledge, and presents a plan for suggested reorganization in terms of basic concepts.

The Business Man and His Health. JESSE F. WILLIAMS. 175 pp. $2.00. Whittlesey House.

This book is addressed to those who spend many hours each day in sedentary labors indoors. The author analyzes the specific problem of the modern business man, and proposes a simple regimen for attaining and retaining good health.

THE SCIENTIFIC MONTHLY

JUNE, 1932

THE ORIGIN OF THE GAMMA-RAYS[1]

By LORD RUTHERFORD

CAVENDISH LABORATORY, CAMBRIDGE UNIVERSITY

It has long been known that some of the radioelements emit a penetrating type of x-rays known as the gamma-rays. It is clear that these radiations arising from the nucleus of the radioactive atom represent, in a sense, some of the characteristic modes of vibration of the nuclear structure. The wave-length and quantum energy of many of the stronger lines in the complicated gamma-ray spectrum have been determined by different methods with concordant results. It has been difficult to determine with certainty the origin of this radiation. It was at first supposed that it must arise from the motions of electrons in the nucleus, but in recent years there has been a growing belief that the radiation is connected with the transition of an alpha-particle or proton which forms part of the nuclear structure. It is not an easy matter to distinguish between the various hypotheses since very little is known about the detailed structure of the nucleus. Fortunately, during the last two years, two different methods of attack on this problem have been developed. The first depends on an analysis of the groups of long range alpha-particles which are emitted in small numbers from radium C and thorium C, and the other the analysis of the fine structure shown in the emission of alpha-rays from certain bodies. It may be supposed that the emission of a beta-particle during a transformation causes a violent disturbance in the resulting nucleus, some of the constituent alpha-particles being raised to a much higher level of energy than the normal. These alpha-particles are unstable and after a very short interval fall back to the normal level emitting their surplus energy in the form of a gamma-ray of definite frequency. According to the ideas of wave-mechanics, in this short interval there is a small chance that some of the alpha-particles in the higher levels can escape from the nucleus. On these views, the escaping alpha-particles represent the long range alpha-particles observed and the energy of the alpha-particles given the value of the energy level in the nucleus which it occupied before its escape. Following out these ideas, the long range alpha-particles which escape from radium C have been carefully analyzed using the new electrical methods of counting alpha-particles

Nine distinct groups of particles were observed and the energies of alpha-

[1] Abstract of a lecture delivered before the Royal Institution on Friday, March 18, 1932.

particles forming each group were determined. The differences of energy between the various groups was found to be closely connected with the energy of some of the most prominent gamma-rays in the spectrum, and, in general, the experiments gave strong evidence that the gamma-rays had their origin in the transition of one or more alpha-particles in an excited nucleus.

It has generally been supposed that in a radioactive transformation all the alpha-particles are expelled with identical speed. This is certainly the case for most bodies, but Rosenblum found that the element thorium C emitted not one but five distinct groups of alpha-particles. The discovery was made possible by making use of the great Paris electromagnet in order to bend the alpha-particles into semi-circle. Gamow pointed out that the appearance of such a "fine structure" in the alpha-ray emission should be accompanied by the liberation of gamma-rays.

Owing to certain experimental difficulties it is not easy to obtain a clear-cut decision on this point. Ellis concludes from his experiments that Gamow's view is correct, but Meitner, from similar experiments, reached an opposite conclusion. In view of this difference of opinion, I have made in conjunction with Mr. Bowden, some experiments to throw light on this problem in another way. Recently Lewis and Wynn Williams found that the actinium emanation emitted two distinct groups of alpha-particles differing in energy by about 340,000 volts. It was seen that this observation offered a simple method of testing the theory of Gamow. The emanation was carried by a current of air into a separate chamber and the emission of beta and gamma-rays directly tested. It was found that the transformation of the emanation was accompanied by a weak beta-radiation and a strong gamma-radiation. The experimental results were in good accord with the theory, and thus showed that the presence of a "fine structure" in the alpha-ray emission is accompanied by the emission of gamma-rays. At the same time, the results afford strong corroborative evidence that the gamma-rays have their origin in the transitions of an alpha-particle in an excited nucleus.

It is of interest to consider how far these views can be carried into the region of the artificial disintegration of the elements resulting from the bombardment of certain light elements by alpha-particles. In some of these disintegrations it is necessary to assume that the alpha-particle can be captured in different energy levels, and that a gamma-radiation is emitted as a result of the transition between the two levels. Penetrating radiations have, in fact, been observed in several cases when light elements are bombarded by alpha-particles. Some of these cases are of peculiar interest.

The Radiation from Beryllium and the Neutron

In examining the artificial disintegration of light elements under the action of alpha-rays, Bothe and Becker, in 1930, noted that beryllium under alpha-ray bombardment, did not emit protons like boron or nitrogen, but gave out a weak radiation which was more penetrating in character than the gamma-rays from radium. The absorption of this radiation in its passage through matter was later examined in detail by Mme. Curie-Joliot and M. Joliot and by Webster.

It is usual in experiments of this kind

to employ active preparations of polonium on a metal disc as a source of alpha-rays. This source is very convenient for the purpose, as the results are not obscured by the presence of beta and gamma-rays which are so freely emitted from other alpha-ray sources such as radium C and thorium C.

In examining the absorption of this beryllium radiation by the ionization method, Mme. Curie-Joliot and M. Joliot made the striking observation that hydrogen material, when exposed to this radiation, emitted swift protons. In explanation, they suggested that the protons gained their energy by a radiation recoil in a process similar to the well-known Compton effect, and estimated that the quantum energy of the radiation must be of the order of 50 million electron volts.

J. Chadwick, using direct counting methods of great sensitiveness, found swift recoil atoms were liberated not only in the passage of the radiation through hydrogen, but also in other light elements including helium, lithium, beryllium, carbon, air and argon. In a letter in *Nature* of February 27 he pointed out that the results in this and other directions were difficult to reconcile with the hypothesis of a quantum of radiant energy of such high frequency. He suggested that the effects observed were not due to a gamma-radiation at all, but to the liberation from the bombarded beryllium of a stream of swift uncharged particles or "neutrons."

The idea of the possible existence of neutrons, that is, of a very close combination of a proton and electron to form an uncharged nuclear unit of mass nearly 1, is not new to science, but it has been very difficult to find any definite evidence of its existence. Rutherford discussed the properties of such a neutron in the Bakerian Lecture before the Royal Society in 1920, and both the late Dr. Glasson and Dr. Roberts made experiments in the Cavendish Laboratory to test whether neutrons were produced in strong electric discharge through hydrogen, but without success.

It is to be anticipated that a projected neutron would produce little if any ionization in its passage through matter, and would pass freely through the outer structure of atoms. A swift neutron should, however, indicate its presence by the recoil of an atomic nucleus with which it collided. This recoiling nucleus would spend its energy of motion in ionizing the gas, and should thus be readily detected by its electrical effect or by the trail of water drops it produces in a Wilson expansion chamber. In some respects, however, the effects produced by a neutron would be very similar to those due to a quantum of high frequency radiation, and careful experiment is required to distinguish between them.

A discussion was given on the present state of the experimental evidence on this important problem. The velocity of the neutron at the moment of its liberation is estimated to be about 3×10^9 cm./sec., or about one tenth of the velocity of light. By comparison of the velocity of recoil of different atoms, Chadwick finds that the mass of the neutron is about the same as that of the hydrogen atom. In addition, the velocity of recoil of a given atom falls off when the radiation is passed through increasing thicknesses of an absorbing material like lead. This is exactly the behavior to be expected for the neutron, but not for a high frequency radiation.

Very valuable information on this problem can be obtained by photographing the effects due to the passage of this

new type of radiation through a Wilson expansion chamber. A number of such experiments have been made by N. Feather and P. I. Dee in the Cavendish Laboratory in association with Dr. Chadwick. For example, it is to be anticipated that the neutron would occasionally collide with the electrons in its path, and thus give rise to an electron track of maximum length corresponding to twice the velocity of the neutron. This is exactly analogous to the well known production of delta-particles by the passage of alpha-particles through gases. Several such short electron tracks have been photographed by Dee which have about the right length, and for which it is difficult to suggest any other explanation. Feather has obtained photographs of more than a hundred recoil tracks produced in an expansion chamber filled with nitrogen. He has observed another very interesting effect. In addition to the straight recoil tracks, he has obtained photographs of a number of branching tracks which indicate that the nitrogen nucleus has disintegrated in a novel way. These branch tracks are believed to be produced by the recoiling nucleus and by some particle which is ejected from the struck nucleus. The identity of this latter particle has not yet been definitely established.

It will take time to analyze the results obtained, and to examine the effects produced in other gases. The peculiar properties of the neutron allow it to approach closely, or even to enter, nuclei of high atomic number, and it will be of great interest to study the effects of such collisions. It is, however, evident that this new radiation has surprising properties, and there is every promise that it may prove an effective agent in extending our knowledge of the artificial disintegration of elements. It will, for example, be of much interest to decide whether the neutron is captured in such disintegrating collisions, or whether it merely passes through the nucleus on which it has such a catastrophic effect.

Mme. Curie-Joliot and M. Joliot and Dee have independently noted that some swift electron tracks are observed in the expansion chamber. The exact origin and nature of these particles will require careful examination. It is possible that a gamma-radiation is emitted from beryllium as well as the neutron. Mme. Curie-Joliot and M. Joliot found that the radiation from boron bombarded by alpha-particles behaved similarly to that from beryllium. It is possible that other elements will also give rise to radiations of this kind.

Whatever may be the final explanation of the interesting facts observed, it is clear that if they are due to a quantum of radiation, we must relinquish the laws of the conservation of energy and of momentum in the production of this radiation and its interaction with matter. If we wish to retain these laws, the neutron hypothesis seems the only alternative. In any case it is evident that these new discoveries have opened up a new region of research which is of great interest and promise.

THE MASTER KEY OF SCIENCE

REVEALING THE UNIVERSE THROUGH THE SPECTROSCOPE[1]

By HENRY NORRIS RUSSELL

PROFESSOR OF ASTRONOMY, PRINCETON UNIVERSITY

The great French philosopher of the last century, Auguste Comte, was an exceedingly well-informed and versatile man, but it was he who once remarked: "There are some things of which the human race must forever remain in ignorance; for example, the chemical composition of the heavenly bodies." To Comte and the other intelligent men of his time, this problem seemed hopelessly insoluble; there was no way of attacking it.

Of course this statement sounds ridiculous to us now. It became ridiculous because man's dream came true of a master key that would unlock many doors, one after another, and so open up many new realms of knowledge.

That master key was the spectroscope. No sooner was it discovered than the composition of the heavenly bodies, previously unknowable, became an open book. With its use, many of the familiar chemical elements were identified in the sun, and not long after, in the stars. Later work has extended the number of elements identified in the sun to sixty, and spectroscopic study has shown that the atmosphere of Mars contains oxygen and water vapor, while that of Venus shows no signs of them.

All the stronger lines in the spectra of the sun and stars and a host of the weaker ones have been identified. It has been demonstrated that the same atoms are present on earth that are also present in the remotest nebulae, in the relatively cold tail of a comet, and in the intensely heated surface of a white star. By showing these things, the spectroscope has given the most impressive of all proofs of the unity of nature.

This achievement has been described in poetry, as it should be, by Edmund Clarence Stedman, in one of his more philosophical poems "Corda Concordia." The stanza in which this is done is such good science, as well as such good poetry, that I would like to quote it:

White orbs like angels pass
Before the triple glass,
That men may scan the record of each flame,—
Of spectral line and line
The legendry divine,—
Finding their mould the same, and aye the same,
The atoms that we knew before
Of which ourselves are made,—dust, and no more.

It is more than two hundred years since Newton, passing his beam of light in a darkened room through a prism, saw the rainbow-colored streak of light upon the wall as the rays of different color were refracted in different amount by the prism, and so was led to realize the composite nature of white light. Unfortunately, Newton took his light through a small round hole and he took it from the large round sun; consequently, even if the sun had been all one color, the image that he would have had thrown on the wall would have been like the image that he got when it came through a pinhole in the window shade. If only he had had the wit to set up a narrow slit so that the image would have been sharp and not round, the master key might have been discovered.

[1] An address delivered at the inauguration of the spectroscopic laboratories of the Massachusetts Institute of Technology, February 25, 1932.

Just after the first half of the nineteenth century was over, Kirchhoff and Bunsen made that simple but fundamental mechanical change. Really this master key was found in a narrow slit—simply in letting your light into this prismatic instrument through a slit so narrow that you obtained a sharply defined image. As soon as that was done, as soon as they took the light through a narrow slit into their prism, with an eyepiece to look at it and a couple of other lenses to make the light go in parallel rays through the prism—the new doors were opened and the new worlds free to conquer.

The next necessary advancement was the development of a more delicate method of spectrum analysis. This came with Rowland, the great Johns Hopkins physicist in the nineties. He developed an engine for ruling diffraction gratings, the device that is used for breaking light up into its components. The best of Rowland's gratings are the joy, the envy and the despair of the investigators today—the joy of the man who has one, the envy of his colleagues, and the despair of the man who tries to make one as good. Rowland devoted years to the study of the solar spectrum and reported and recorded in it the position of 20,000 lines, each one carrying its own story of some substance in the sun. When Rowland was through his work, thirty-six of the chemical elements had been identified in the sun. Since that day, of course, a number more have been added because plates have been developed which are sensitive to the red end of the spectrum, and Rowland had no such plates available. Partly for that reason, and partly because some substances are now available of which Rowland could not get specimens, sixty chemical elements have now been identified in the sun—most of them with certainty.

In the stars, we can not observe such immense detail as we can in the sun, although the big spectroscopes that are now being attached to the great refractors such as the Mt. Wilson 100" telescope give us an amazing amount of information, and dozens of different chemical elements have been definitely identified in the stars.

The minute shift in the position of the lines due to motions of approach or recession has enabled us to detect and measure the rotation of the sun and the planets, to prove that Saturn's rings are not solid, but composed of myriads of tiny satellites, and to get one of the most accurate determinations of the sun's distance. Applied to the stars, it has determined the sun's motion among them, the distances of hundreds of individual stars, and the average for thousands more; has revealed hundreds of double stars too close to be resolved by the telescope, and determined the masses and even the diameters of some of them; and has disclosed those amazingly rapid motions of the remote nebulae—some as high as 15,000 miles a second—which point the way to new conceptions of the nature, the past and the future of the material universe. Spectroscopic tests have shown that the nebulae are of two kinds, one consisting of masses of luminous gas; the others, giving light like stars, must themselves be great clusters of stars at gigantic distances.

If the spectroscope has thus proved so profitable to the astronomer, what has it accomplished for scientists in other fields? The chemist owes to spectroscopy the discovery of at least ten of the elements, some by optical methods, others more recently by the aid of x-rays. Among these is helium, which was detected in the sun and its nature as a light gas correctly interpreted more than twenty years before it was "run to earth."

The classical physicist finds in the spectroscopic data his most precise standards of length, and some of his more accurate methods of measurement.

My friend, Dr. Meggers, of the Bureau of Standards, and his associates have developed very practical spectroscopy recently. Suppose, for example, you have some fusible plugs that are used in our overhead sprinkler systems. They are made of a fusible alloy which will be greatly damaged if it has any more than the most minute quantity of iron in it. To find this out by chemical analysis is a slow and tedious process; but you can take one of these plugs and test it with the spectroscope, and if the strong lines of iron show up, you know there is iron there. Comparative tests with materials of different composition give you an idea of the safe limits. Thus, with the spectroscope you can test these alloys in a minute part of the time that chemical composition requires.

But it is in the realm of atomic physics that spectroscopy has played its greatest rôle. Fifty years ago, Lockyer, from a study of the spectra of electric arcs and sparks, and of the stars, concluded that, in the spark and in the hotter stars, ordinary atoms are decomposed into products which give different spectral lines. This bold generalization was fully justified forty years afterward, by the development of the theory of ionization.

About forty years ago, series of lines were detected in many of the simpler spectra, and found to be representable by formulae in which the "Rydberg constant," common to all spectra, appeared. Here was evidence of some uniform feature in the constitution of the different atoms. The Zeeman effect, according to which a spectral line emitted by a source placed in a strong magnetic field is split up into polarized components, again showed features common to different atoms, and suggesting the presence within them of moving electrical charges. The Bohr-Rutherford theory of atomic structure—with electrons in orbital motion around a nucleus—was based very largely on these spectroscopic data. It accounted at once for the typical spectral series of hydrogen, and accurately predicted other series in the infra-red and ultra-violet. With simple modifications, it explained the more complicated system of series in the spectra of the alkalies. The multiple character of the terms of the series was later interpreted as a result of the spin of the electron—thus increasing the "astronomical" resemblance of the atom-model; while the appearance of numerous terms in the more complex spectra was accounted for by differently quantized inclinations of the electron orbits. The complex multiplets of lines found in the spectra were thus fully explained. In its final form (due to Hund) this theory has been brilliantly successful in elucidating the structure of atoms and interpreting and even predicting the details of their spectra. Work in this field has been very active, and only the most complex spectra (rare earths and some heavy metals) and those of a few very rare elements remain to be deciphered.

In the case of molecules, changes in the states of oscillation and rotation of the nuclei, as well as in the electronic states, are possible, and the spectra are much more intricate, consisting of complex bands comprised of closely packed lines. Those of diatomic molecules are now well understood—with important gains in our knowledge of molecular structure and the nature of chemical "affinity,"—and the still more intricate polyatomic molecules show signs of yielding. Different isotopes of the same element, when present in compounds, often give widely separated bands. From these, new isotopes of oxygen, nitrogen and carbon have been discovered, and the ratio of the masses of the different atoms determined with extreme precision. In atomic spectra, the isotope effect is extremely small, except for hydrogen—where it has recently permitted the identification of an isotope of double weight.

Fine-structure in the lines of heavier

atoms arises partly from the presence of isotopes, partly from some sort of "spin" within the atomic nucleus, and its study affords a promising approach to the problem of nuclear structure.

While all this was going on, x-rays were also found to contain monochromatic radiations, observable by using the atoms in a crystal as a diffraction grating. These spectra have given us information about the interior of atoms, comparable with that which optical spectra furnish concerning the exterior. They are much simpler than the latter, and now furnish the chemist with his most delicate test for the detection of new elements. Incidentally, they make it certain that except for the few well-recognized gaps, no elements lighter than uranium remain to be discovered.

Working in the opposite direction, x-ray spectroscopy opens the door to another untrodden realm—the exact study of the arrangement of atoms in crystals, which can now be specified in minute detail.

All through these triumphs ran a discordant note. Certain numerical relations—notably in the Zeeman effect—though exact, differed systematically from those predicted by the orbit theory, and every calculation based on the relative positions of electrons in these orbits led to a wrong answer. This discrepancy has vanished since the orbital picture of the atom was replaced by the difficultly visualizable wave-mechanics or the wholly unpicturable matrix-theory. When a modern lecturer tries to draw an atom on the blackboard, he uses no chalk, but an eraser, and constructs a smudge illustrating the relative probability of finding a unit-charge in different regions. But as a means of calculation—interpreting and, on occasion, predicting, the results of precise observation, the new theory advances from conquest to conquest.

The ramifications of these new ideas throughout the range of molecular and atomic physics are too numerous to mention. To take but one instance at random, the magnetic susceptibilities of solutions of salts of the rare earths may be fully explained by the theory of spectral structure—even though the spectra of the trebly ionized atoms (upon which these depend) have not yet been observed.

There is probably no field in which the new spectroscopy has been of more aid than in astrophysics. The recognition that Lockyer's enhanced lines are produced by ionized atoms, and the general application of the laws of ionization to stellar atmospheres have transformed our whole view-point. We know now that the disappearance of the lines of the metals from the hot stars means only that they have been so highly ionized that they no longer give lines in the observable region, and that the lines of the permanent gases, and the non-metals generally, are weak or absent in the cooler stars because their atoms are not highly enough excited to be able to absorb the observable lines. From measures of line-width, and also by study of multiplets, the actual number of atoms which produce a given spectral line may be estimated, and an approximate quantitative analysis made of the atmospheres of the sun and stars. The results indicate a remarkable similarity of composition, despite the great differences in the spectra of hot and cool stars. The relative abundance of the elements is similar to that in the earth's crust or in meteorites, with one noteworthy exception. Hydrogen—a minor constituent here—is overwhelmingly predominant in the stars. (The excess very likely escaped during the formation of our planet.) Both the temperature and pressure of a star's atmosphere may be found from the intensities of the spectral lines. The former agree with the values deduced from the colors of star-light; the latter are surprisingly small, and indicate that the atmospheres are of exceedingly low

density. The whole atmosphere of the sun, brought to standard temperature and pressure, would make a layer of gas less than a hundred feet thick, of which the metallic vapors form about one per cent.

A similar conclusion was reached more than forty years ago by Lockyer, by the simple process of comparing the sodium lines in the solar spectrum with those absorbed by the vapor present in a Bunsen flame. The sun's atmosphere, of course, is not sharply bounded at the bottom; it grows hazier owing to the increasing density of the free electrons and ions, and passes into the luminous photosphere. The principles upon which this increasing opacity can be calculated are essentially spectroscopic, and the data regarding the ionization and excitation potentials of atoms, which it requires, have been derived spectroscopically.

Two more applications may be mentioned—to matter in extreme states of condensation and rarefaction.

From the spectroscopic data regarding atoms it follows that, at very high temperatures, inside the stars, they will be completely ionized down to bare nuclei and electrons. Matter in this state should be exceedingly compressible, but not infinitely so—the limiting factor being the degeneracy of the gas (in the sense of the new quantum theory) at a density several hundred thousand times that of water. The problematical white dwarf stars, like the companion of Sirius, show conclusive evidence of being in this state, while the shift towards the red of the lines in their spectra (coming from the outer atmosphere) affords an important confirmation of general relativity. At the other extreme, the gaseous nebulae—which from gravitational considerations must be of extreme tenuity—show spectral lines which were long a tantalizing problem. Modern spectroscopy revealed the existence of metastable atomic states, from which light-producing transitions would not occur unless the individual atoms were left undisturbed much longer than they would be except in an exceedingly rarefied gas. Bowen thus identified the nebular lines as "forbidden" lines of the sort produced by the most familiar elements, oxygen and nitrogen above all. The hypothetical unknown element nebulium thus very literally vanished into thin air.

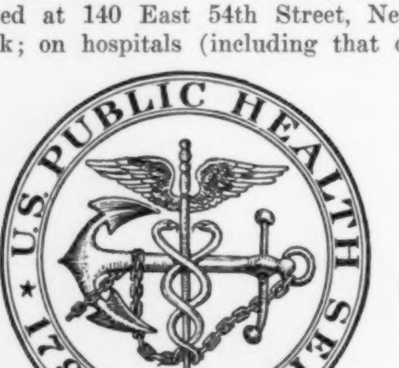
THE CADUCEUS

By STUART L. TYSON, D.D. (OXON.)

PELHAM MANOR, N. Y.

IN view of the evident pride of our physicians in the emblem of their profession, as manifested, *e.g.*, on motor cars, on seals, charters, façades of medical buildings, hospital *stoai*, etc., it is curious to note how many there are who reveal, in the manifold expressions of their sentiment, an entirely erroneous conception of what in fact is the emblem of the healing art.

Ask the average *medicus* to describe the *signum* of Asklepios, the god of medicine; he will be almost certain to reply that it consists essentially of a *Caduceus*, *i.e.*, a wand with two serpents intertwined. Should the *advocatus diaboli* express doubt as to the correctness of the answer, he will perhaps be confronted with the *sigillum* of the U. S. Public Health Service, the insignia of the U. S. Army Medical Corps, the seals of not a few county medical societies, adornments on many buildings consecrated to the profession, such as the splendid "Medical Chambers" recently completed at 140 East 54th Street, New York; on hospitals (including that of the newest *Asclepieion* at New Haven, the University Health Department Building), etc., all of which exhibit the two snakes around the wand or forked rod. If the *paganus* be still skeptical, he may be referred to that fine book, "Devils, Drugs, and Doctors," by Dr. H. W. Haggard, associate professor of applied physiology at Yale, where on p. 15 f. (1st ed., 1929) it is noted that "the symbol of Aesculapius, the Caduceus—the two snakes twined on a staff—has survived, and is still used to-day as a medical emblem." Or he may even be shown the words of that prince of physicians, Sir William Osler, who, in his Silliman Lectures at Yale in 1913 on "The Evolution of Modern Medicine," the proofs of which were never wholly revised by the author,[1] seems (but only seems: for while the statement is unfortunately accurate for many groups in the U. S., with the notable exception of the A. M. A. since 1912,[2] the entire context, both photographic and verbal, negates the assumption) to lend countenance to the error. "Asklepios . . . remains our patron saint, our emblematic god of healing, whose figure with the *serpents* [italics mine] appears in our seals and charters" (p. 43). In the past six months the present writer has questioned thirty-one physicians as to the emblem of the healing god and in twenty-seven instances has received as



SEAL OF THE U. S. PUBLIC HEALTH SERVICE.

[1] *Cf.* Dr. Harvey Cushing, "Life of Sir Wm. Osler," Vol. II, pp. 292, 377, 385, 436: also "Annals of Medical History," Vol. IV, p. 214.

[2] "For a time the Caduceus was used as an emblem by the American Medical Association, but in 1912, after considerable discussion, the official emblem embodying the Aesculapian rod was adopted and is still in use." B. S. Engle, *The Classical Journal*, Vol. XXV, p. 206.

FAÇADE OF MEDICAL CHAMBERS, NEW YORK, SHOWING CADUCEUS.

de fide the reply that the wand with *two* snakes constitutes his *symbolum.*

It would ill become a mere layman to rail at these Asklepiads; but a professional student of the history of his art might well be tempted, on recalling the answers of his twenty-seven fellow-practitioners, to breathe the pious prayer of Thersites in "Troilus and Cressida":

> O thou great thunder-darter of Olympus! forget that thou art Jove, the king of Gods; and, Mercury, lose all the serpentine craft of thy Caduceus, if ye take not that little, little, less-than-little wit from them that they have!

For it is an incontrovertible fact that the wand with the two serpents is the symbol, not of Asklepios, but of Hermes (*Lat.* Mercury), of whose connection

TRUE AESCULAPIAN SYMBOL, AS EMPLOYED BY THE A.M.A.

with the healing art there not only exists scarcely a chemical trace, but most of whose positive attributes are wholly alien to the noble profession of medicine; while on the other hand, the heavy staff or club, bearing a single twined snake, from the early days of Greek mythology until at least the period of Henry VIII, has invariably been associated with him whom all physicians of the Western world revere, not only as the very *Deus Medicinae,* but also as the fabled ancestor of Hippocrates, the true *Pater Medicinae.*

Let us first examine the term "Caduceus"—or probably more accurately "Caduceum."[3] It is the Latin adaptation of the Doric καρύκειον, or Æolic καρύκιον, rather than of the Attic form κηρύκειον, (the ρ becoming d, as ad = αρ), "a herald's wand," derived from κῆρυξ, "a herald" or "ambassador," in turn evolved from κηρυσσεῖν, "to an-

[3] It is a curious fact that neither Cicero, Nepos, Livy nor Pliny happens to employ the nominative, and it is therefore difficult to determine the predominant gender in antiquity; but inasmuch as the term is practically a transliteration of the Greek neuter adjective, it would seem (as against English usage) to be etymologically a neuter.

nounce": the neuter adjectival substantive denoting the symbol of the official state messenger as he went out to treat of peace. In the Greek world it was originally a shepherd's crook,[4] a forked olive branch adorned at first with two fillets of wool, then with white ribbons, and later (a recrudescence, as will shortly be shown, of a far earlier Eastern tradition), with two snakes intertwined, *the* Caduceus *par excellence*, the magic wand of Hermes, the heavenly messenger of the gods. This last, according to the monumental Oxford Historical Dictionary, "is its earliest and proper sense in English."[5]

Next, as to Hermes or Mercury, the true bearer of the Caduceus.[6] He was the son of Zeus and Maia, as Asklepios was begotten by the healing god Apollo. A late myth, however, makes him half-brother of the god of medicine, whose

THE CADUCEUS, ERRONEOUSLY EMPLOYED BY MANY PHYSICIANS AS THE SYMBOL OF THEIR PROFESSION.

daughter Hygeia he is said to have married. This is about the extent of his connection with the healing art, unless, indeed, the giving or withholding of sleep and the promotion of fertility be regarded as therapeutic. However, in Tanagra he was believed to have averted a pestilence,[7] an action common to more than one of the Olympiads. But inasmuch as the respective symbols of the two gods were superficially so similar, it was perhaps only natural, in the ebb and flow of classical studies, that from time to time they should become confounded. According to one myth, Hermes obtained the Caduceus as follows: With great ingenuity he had evolved the lyre from the shell of a tortoise, and playing thereon before the enchanted Apollo what may be presumed to have been the Greek prototype of the Fifth Symphony, received in return for the gift of the instrument to the spellbound god, an ambassadorial portfolio to mediate between the gods and men. Whereupon, as now high heaven's herald, he was given the magic forked wand, the *signum* of the peace-bringer, ultimately decorated with the two intertwined serpents, and sometimes also with wings, as symbolizing his incredible speed. Historically, the Caduceus, adorned with a male and female serpent intertwined, carries us back to a period far earlier than that with which we are at present concerned, and is definitely associated with the idea of fertility, which, as just stated, Hermes was believed to promote.[8] Greek and Roman myth supply several stories as to the *raison d'être* of the two snakes on Hermes' wand of office. Perhaps that related by Hyginus, in his "Poeticon As-

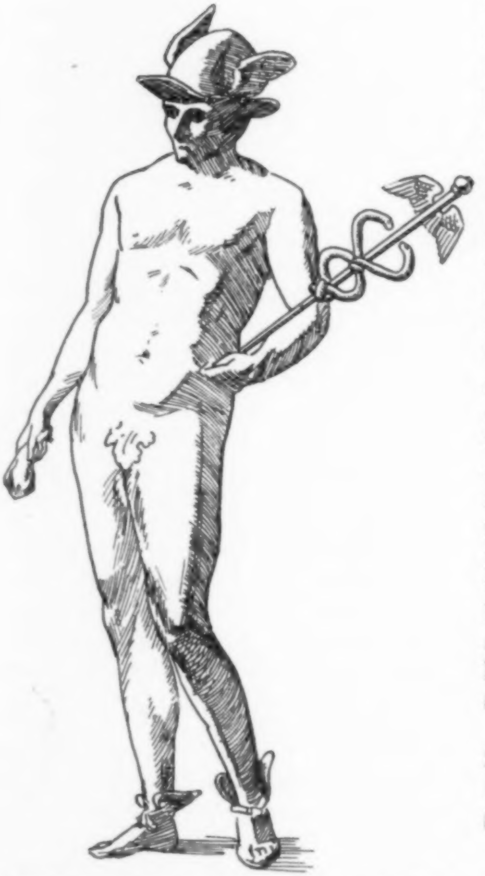
[4] Farnell, "Cults of the Greek States," Vol. V, p. 20.

[5] Thus Spenser, in 1591, referring to Mercury: "And in his hand
He took Caduceus, his snakie wand,
With which the damnéd ghosts he governeth,
And furies rules, and Tartare tempereth."

[6] Cf. Ovid, *Metam.*, 8, 627, who refers to him as "Caducifer." Facciolatus and Forcellinus, in their "Totius Latinitatis Lexicon," cite the following from an old inscription: "*Mercurius petasatus et caduceatus*"—"Mercury with his travelling cap on and equipped with the Caduceus."

[7] Paus. IX, 22, 1.

[8] For the Caduceus of this period, see the scholarly essay, "The Babylonian Origin of Hermes the snake-god, and of the Caduceus," by A. L. Frothingham, in the American Journal of Archaeology, 2nd Series, Vol. XX, p. 175 ff. "This proto-Hermes was always a snake-god. . . . But it is an essential element of his function that he was not a single snake . . . but the double snake, male and female, the most prolific form of copulation in the animal kingdom. For this reason the emblem of the god was the Kerykeion or Caduceus, a pair of snakes wound around a wand or sceptre."



HERMES, WITH CADUCEUS AND WELL-FILLED PURSE. (ARLES).

tronomicon," will do as well as any other. "Mercury . . . saw two serpents entwined in mortal combat. Separating them with his wand, he thereby induced a state of mutual peace. As a result of this episode, the wand with two serpents intertwined came to be regarded as the sign of peace." Macrobius,[9] however, evidently recalling the earlier Oriental tradition, says that the two serpents were "*non dimicantes sed coeuntes . . . pressis osculis ambitum circuli jungunt*"!

How singularly inappropriate is the use of his emblem by physicians may be realized by recalling some of his functions. As god of the high-road and the market-place Hermes was perhaps above all else the patron of commerce and of the fat purse: as a corollary, he was the special protector of traveling salesmen. As spokesman for the gods, he not only brought peace on earth (occasionally even the peace of death),[10] but his silver-tongued eloquence could always make "the worse appear the better cause.[11] From this latter point of view, would not his symbol be suitable for certain Congressmen, all medical quacks, book agents and purveyors of vacuum cleaners, rather than for the straight-thinking, straight-speaking therapeutist? As conductor of the dead to their subterranean abode,[12] his emblem would seem more appropriate on a hearse than on a physician's car. And so one might go through the list. When but a new-born baby, for instance, he escaped from his cradle and stole the oxen of Apollo; exhibiting even at that tender age the sinister quality of his genes.

The following fair *florilegium*, culled from the "Homeric Hymn" to Hermes (Shelley's translation), illustrates a great unknown Greek's judgment of one

9 *Saturn.* C. 19 f.—cited by Facciolatus and Forcellinus *sub v.* "*Caduceus.*"

10 *Cf.* his murder of Argus: Apollod. II, 1, 3.

11 "As an adroit speaker, he was especially employed as messenger, when eloquence was required to attain the desired object." L. Schmitz, D.G.R.B.M., II, p. 412.

12 Od. XXIV, 1, ff.

CADUCEUS AS EMBLEM ON PHYSICIAN'S CAR.

whose emblem so many of our medical men still employ. The good god himself meekly confesses that "I am the king of robbers." Apollo cries:

I fear thee and thy chameleon spirit. . . .
Thieves love and worship thee—it is thy merit
To make all mortal business ebb and flow by "roguery";

and he prophesies that

This among the gods shall be your gift—
To be considered as the Lord of those
Who swindle, house-break, sheep-steal and shop-lift.
A schemer subtle beyond all belief.
I never saw his like either in heaven or upon earth for knavery or craft.

To crown his character, he was a murderer.[13] Perhaps one of his most amiable characteristics, apart from his proclamations of "peace, peace" (occasionally when there was no peace), and his devotion to athletics, was his patronage of the ancient and honorable pastime of craps, over which, in the Greek world, he seems to have presided with relative impartiality. But in whatever capacity, good or bad, he is exhibited with his two serpents, his relationship to medicine is tolerably near absolute zero.

Far otherwise is the case with Asklepios, the divine healer, invariably depicted with the single snake, either coiled round his knotted staff, by his side, or being fed by his daughter Hygeia, and whose whole "life" was selflessly devoted to the amelioration of human suffering. He conducted no souls into the underworld. On the contrary, he was ultimately electrocuted by Zeus on complaint of Pluto, who averred that by his supernatural medical skill he was depopulating hell and so reversing the whole cosmic order! Nevertheless, so great was his celestial fame that, by way of compensation, he was forthwith translated into heaven as a constellation, "The Serpent-Holder."[14] It appears superfluous to say that he was never pictured in Greek or Graeco-Roman art as bearing the Caduceus, an emblem utterly foreign to him, and with which at no time had he either direct or indirect connection. The very term itself, as wholly devoid of any medical connotation whatsoever, has no place in the Aesculapian vocabulary.

Who he really was—whether god or man—is immaterial to our purpose. Classical students will realize that here as elsewhere in this brief paper, no more than the baldest selection, out of the many and variant myths, has been attempted. It is hoped, however, that the outstanding attributes of the respective gods have been fairly adumbrated. Whether, as many scholars believe, he was originally no more than a Thessalian warrior who "turned" to medicine —as in the Iliad, where he is merely "the blameless physician"—he early became a chthonic snake-god. Sir James Frazer, in his extended note on Pausanias II, 10, expresses his own judgment as follows. "It is tolerably certain that originally Aesculapius was neither more nor less than a serpent, which at a later time was transformed into an anthropomorphic god, with a serpent symbol. . . . The ancients explained the connection of the serpent with Aesculapius by saying that it is the natural symbol of the healing art, since it periodically renews itself by sloughing off its old skin." So in his note on "The Fasti" of Ovid (Vol. 2, p. 132): "It was natural to suppose that a creature which could thus renovate itself could also renew the energies and prolong the life of the sick and suffering. . . . So firmly implanted in the minds of the ancients was this association of the renewal of youth with the sloughing of the skin that both in Greek and Latin the ordinary word for old age was also applied to the slough of serpents." There is perhaps little doubt that the whole matter, in its ultimate analysis, is to be referred to phallic worship, with the ser-

[13] Apollod. *loc. cit.*

[14] Sir T. Clifford Allbutt, "Greek Medicine in Rome," p. 46.

pent itself as phallos. But to follow this up would carry us too far afield.

While the origin of the term "Asklepios" is uncertain, there is some probability that it was derived from a Greek word meaning "the creeper," *i.e.*, one who walks by rolling round and round,[15] again suggesting the snake. He is represented in ancient art as a reverend bearded god,[16] leaning heavily upon a thick knotted staff, around which a serpent is coiled; or sometimes seated, while votive offerings are brought to him, with the serpent by his side. In this latter connection, every one will recall the last poignant words of Socrates when, after drinking the hemlock in his prison and "already growing cold about the groin," "he uncovered his face and spoke for the last time. 'Crito,' he said, 'I owe a cock to Asklepios: do not forget to pay it.' 'It shall be done,' said Crito . . ." and thus died one "who was the wisest and justest, and the best man that I have ever known."[17]

From Epidauros, the splendid seat of his chief healing shrine, Asklepios as a snake came to Athens in 420 B. C., and to Rome in 291, which latter event ultimately gave to the Western world the more familiar Latin equivalent "Aesculapius," the progressive evolution of the term being somewhat as follows:

(1) Aisclapius, (2) Aesclapius, (3) Aisculapius,[18] (4) Aesculapius (*Cf.* the older Epidaurian form 'Αισκλαπιός, and the Thessalian 'Ασκαλαπιός.

AESCULAPIUS. (NAPLES MUSEUM).

Following the ravages of the pestilence at Rome in 293, an embassy was dispatched to Epidauros to secure the services of the god, who in the form of a snake was at length brought in great state by ship up the Tiber;[19] and himself sliding overboard and selecting the *Insula Tiberina* as his home, was forthwith received into the Pantheon, "the first instance of the Romans having adopted a cult from the Greek mother-country." According to Professor Thrämer, of Strassburg, from whose work[20] the above citation is taken, there were no less than 410 localities connected with his cult, testifying at once to

[15] Allbutt, *op. cit.*, p. 46.

[16] J. Harrison, "Prolegomena to the Study of Greek Religion," p. 340 f. "We conceive of Asklepios as he is figured in many a Greek and Graeco-Roman statue, a reverend bearded god, somewhat of the type of Zeus, but characterized by the staff on which he leans and about which is twined a snake. The snake . . . is the symbol of the healing art, and hence the attribute of Asklepios, god of medicine."

[17] Phaedo, LXVI.

[18] So spelt at *Insula Tiberina.*

[19] *Cf.* Livy, *Epit*, XI.

[20] Encl. R. E. VI, pp. 550, 554.

the enormous expansion of the popular belief in the powers of "the Beloved Physician," and to the fact that "the serpent is the perpetual symbol of Aesculapius."[21]

How, then did his symbol become confused with that of Hermes: a phenomenon, so far as I know, confined to-day entirely to the United States? According to Engle,[22] the earliest instance of the confusion is that of the famous Swiss medical printer, Johann Froben (1460–1527), who, evidently familiar with Hermes' Caduceus and also with the New Testament, pictured in his publications a two-serpented wand, surmounted, not by wings but by doves: and over all, as obviously excellent advice for physicians, the Greek original of the saying of Christ, "Be ye wise as serpents and harmless as doves." But in reality there appears no reason to believe he intended his device as the symbol of either Aesculapius or Hermes. On the contrary, it would seem quite clear, from the plural number both of serpents and doves, taken with the words of the overarching motto, that he had constructed his own symbolism for the emblem. However this may be, his fame appears in some measure to have set a precedent; for Sir William Butts, physisian to Henry VIII, employed the erroneous *signum;* and a few years later Dr. John Caius presented to Gonville and Caius College, Cambridge, a silver Caduceus, as to the significance of which he wrote his own Latin interpretation.[23]

We do not hear of it again until 1844, when it appears on the title-pages of the medical publisher J. S. M. Churchill, of London; and so far as the present writer is aware, this is the last that is heard of it in England; for the true Aesculapian emblem is used to-day by the Royal Army Medical Corps, and also by the French Medical Military Service. But in 1856 the two snakes once more re-appear, this time on the chevrons of hospital stewards of the U. S. Army; later, on the seal of the U. S. Public Health Service, and in 1902 on the uniforms of the U. S. Army medical officers. From these sources, apparently, the erroneous symbol[24] extended over nearly the whole of the American medical profession, large numbers of which still believe that what in reality is the emblem of the god of thieves[25] is that of the immortal healer, "the blameless physician" of the Iliad.

As one recalls the cumulative accomplishments of their respective disciples throughout the ages, from the primitive *incubatio* of Epidauros to the triumphs of modern preventive medicine on the one hand, and from the petty thievery of Hellas to the highly organized banditry of to-day on the other; to the follower, whether of Asklepios or of Hermes, it might significantly be said in the 20th century, as in the 18th, the epitaph over the door of St. Paul's Cathedral reminded those who desired a magnificent mausoleum for the great architect of the famous edifice, *"Si monumentum requiris, circumspice!"*

[21] Schmitz, *Op. cit.* Vol. I, p. 45.

[22] *Op. cit.*, p. 207. *Cf.* also "Annals of Medical History," Vol. IV, p. 301 *ff.*

[23] For its text, *Cf.* Classical Journal, Vol. XXV, p. 207.

[24] The contention that the originators of its use in the Army Medical Corps were fully aware it was the symbol of Hermes, and did not intend this non-medical emblem which they placed on the collars of medical officers to have any medical significance whatever, is at once true and irrelevant. Because (without entering upon the symbolism which they attached to it), it was well nigh inevitable, in spite of all hypothetical disclaimers, that the Caduceus, superficially so similar to the Aesculapian staff, and now employed by "Government medical officers," should soon come to be generally regarded "as a symbol of the medical profession" in general (Dorland, "The American Illustrated Medical Dictionary," latest edition, *s.v.* "Caduceus"); and thereupon, by easy stages, to be widely accepted as the emblem of Aesculapius himself. And this is exactly what appears to have happened.

[25] "The patron-god of thieves, liars and defrauders." Farnell, *op. cit.*, V, p. 23.

TIME-CHANGES OF THE EARTH'S MAGNETIC FIELD[1]

By J. A. FLEMING

ACTING DIRECTOR, DEPARTMENT OF TERRESTRIAL MAGNETISM, CARNEGIE INSTITUTION OF WASHINGTON

There is about the Earth a magnetic field. Its cause and origin are veiled in mystery as in the case of that other great natural phenomenon, gravitation. Unlike the latter, one can not immediately recognize the Earth's magnetism through any physical sense. An unexpected fall apprises one of the existence of gravitation, but no bodily effect is noticed in the Earth's magnetic field, although it is real as that of gravity and is subject to relatively greater local anomalies than the gravimetric field.

The familiar compass-needle demonstrates that magnetic forces are present everywhere in the Earth. Ocular evidence of this force may also be obtained by its inductive magnetic action upon a material highly susceptible to such action, for example, an alloy with unusually great capacity for transient induced magnetization in weak magnetic fields such as that of our planet. Permalloy has been developed in recent years to supply the need of such a material to improve cable communication. When a thin long rod of permalloy is directed toward the north magnetic pole of the Earth's field, the magnetization induced in the bar because of that field is quite sufficient to lift small pieces of permalloy. But as the rod is turned with its length at right-angles to the field and thus in the direction least favorable to induction, it loses the magnetism induced by the Earth and will no longer support such metal strips, which fall.

[1] The first in a series of three lectures concerning the magnetic field of the Earth and its atmosphere, delivered at the Carnegie Institution of Washington, on March 8, 1932.

The picture of magnetic phenomena is incomplete if viewed only in a man-made laboratory, even though we can now produce there an artificial magnetic field within a space of a cubic inch which is about 100,000 times more intense than that of the Earth. Fortunately, Nature provides not only the Earth and its atmosphere as a great magnetic laboratory but also continuously performs experiments, utilizing as apparatus the Sun, the Moon and radiations from space. It is, however, only within historic times that we have appreciated the opportunity of putting this great laboratory to human use.

The discovery of the lodestone with its mystical power of attracting particles made of iron paved the way to the development of the magnetic compass, which has been in use by navigators since the eleventh century. This magnetic property of the lodestone—the "leading stone" of the Scandinavians, the "loving stone" of the French—was known to the Greeks according to authentic records some time about the end of the seventh century B. C. Various traditions ascribe such knowledge also to the Chinese as much as 2,600 years before the Christian era, and to the Japanese during the second half of the seventh century, but there is some question as to their authenticity.

In attempting to solve the mystery of the lodestone it was discovered that, when mounted in a block of wood and floated in water, one direction would always be indicated, that is, magnetic north and south. This was followed by

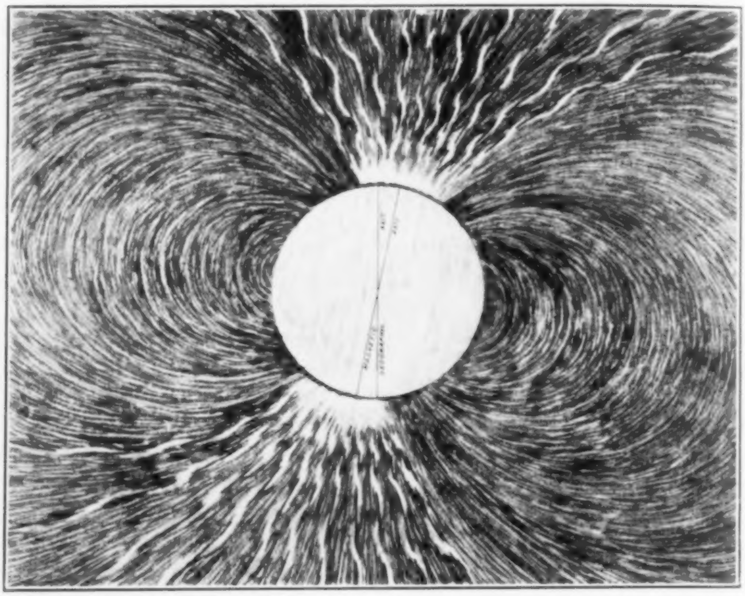


FIG. 1. THE MAGNETIC FIELD ABOUT THE EARTH

the first European treatise on the magnet written about 1269.

That property of the magnetic field of the Earth giving direction to the compass-needle was thus utilized some centuries before Columbus began his voyages to the western hemisphere. He, however, was the first to determine that the compass did not point true north except in certain places. We all know the story of the threatened mutiny on his first transatlantic voyage when the crew saw the compass pointed 10° west of true north instead of north as indicated by the pole-star, and how apparently he shifted the compass-card on its needle during the following night, thus quieting the fears of his men and inducing them to continue. But even to-day there are many who think of the compass-needle as showing direction "true to the pole of the heavens or the polar star."

Magnetic dip or inclination was unknown until 1576, when Robert Norman, a practical seaman and instrument-maker, published "A newe discovered secret and subtill propertie concernying the declinying of the Needle, touched therewith under the plaine of the Horizon." His discovery that the magnetic needle, when mounted on a horizontal axle so as to be free to move in the vertical plane, dipped below the horizon, gave the first hint that the source of the magnetic field of the Earth might be within the globe and not in the stars as previously supposed. It was not until 1600, however, that William Gilbert published his famous volume in which he pointed out that the Earth itself acts to a certain extent as though it were a great spherical magnet. Gilbert's conclusion thus preceded Newton's announcement of universal gravitation. Taken as a whole, the Earth is a feeble magnet. It is possible to magnetize our modern hard steel ten-thousand fold as much. Even so, since the globe is large, its total magnetism is equivalent in effect

to eight hundred quintillion one-pound magnets of our best magnet-steel, could they be placed at its center.

The Earth is not uniformly magnetized and the principal magnetic poles are distant 1,200 miles or more from its geographic poles. The north magnetic pole, first visited a century ago June, 1931, by Ross and again in 1903, by Amundsen, is on Boothia Peninsula in northern Canada. The south magnetic pole, in South Victoria Land, has not yet been visited. Thus the magnetic poles are not diametrically opposite each other, the line joining them passing some 750 miles away from the center of the Earth.

The magnetic field extends far out into space. Four thousand miles above the Earth's surface it is still one eighth as great as at the surface. One may picture it as made of innumerable lines of magnetic force or action closely packed as schematically shown in Fig. 1. These lines of force are parallel to the surface near the plane of the equator, but as they approach the magnetic poles they bend and converge. Minute electrified particles in varying numbers are coming continually from the Sun. Once within the Earth's magnetic field, these particles or corpuscles are entrapped by the outermost lines of magnetic force and travel in paths around them. They get deeper down in our atmosphere in the polar regions, where the magnetic-force lines are steepest. When the electrified particles pass through the atmosphere they cause the air to glow by their impact, causing the brilliant polar-light displays sometimes seen in the northern and southern sky. From simultaneous photographs of aurora, taken at two stations a known distance apart, it has been found that polar-light beams generally do not come closer to the Earth's surface than about 50 miles; some come no closer than 300 miles or more.

The Earth's outer crust or shell, some 50 or more miles thick, is not homogeneous and therefore is not uniform in its magnetic behavior. Thus there are many regions of local magnetic disturbance, such as are caused by magnetic ore-deposits, some so great as to give rise to local poles and other irregularities in the general magnetic field.

The study of the character and behavior of this field therefore calls for observations not only on the surface of our globe but also in its interior and in its atmosphere. This applies particularly to the higher atmospheric limits and to the Earth's enveloping skin

FIG. 1A. THE HEIGHTS OF VARIOUS PHENOMENA IN THE ATMOSPHERE
(AFTER DOBSON)

or crust, where we apparently must look for explanations of those constantly occurring regular and irregular variations with time of the magnetic field which are the subject of this paper.

That our magnetic field is subject to progressive change or secular variation, that is, a slow age-long variation, was first noted by Gellibrand in 1634. In a book published in London (June 12, 1634) entitled "A Discourse Mathematical on the Variation of the Magnetical Needle Together with its Admirable Diminution Lately Discovered" he announced for the first time that "Variation is accompanied with a variation." Besides the secular variation, other more or less regular time-changes include daily inequalities, taking place chiefly during daylight hours and varying in magnitude and character with geographic position, with the seasons of the year, and with disturbances on the Sun. There are also short-period, long-period and sudden-commencement disturbances, commonly designated magnetic storms, apparently accompanying solar disturbance and other cosmical phenomena.

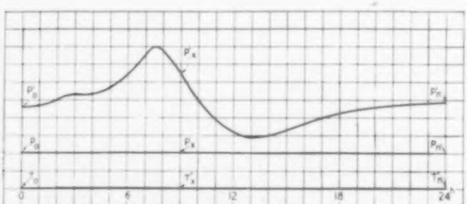


FIG. 2. GRAPH OF DATA VARYING WITH TIME

Much of what is known concerning time-changes can best be visualized graphically. Many of the photographic records upon which conclusions are based are in effect motion pictures of the experiments constantly being performed by Nature in her great laboratory. It is therefore desirable to give first some explanation of one method in common use to represent any quantity which varies with the passing of time or with some other variable. Consider, for example,

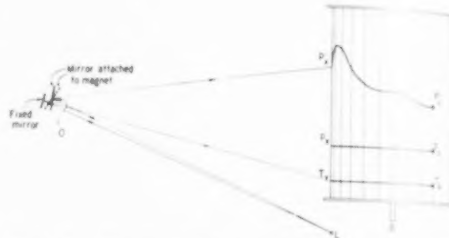


FIG. 3. SCHEMATIC DIAGRAM SHOWING PRINCIPLE OF RECORDING MAGNETIC VARIATIONS

any period over which a certain quantity is observed. It may be for centuries, for years, for months, for days, for minutes or for any other period represented by a straight reference-line as the one from T_o to T_n in Fig. 2. That line may be

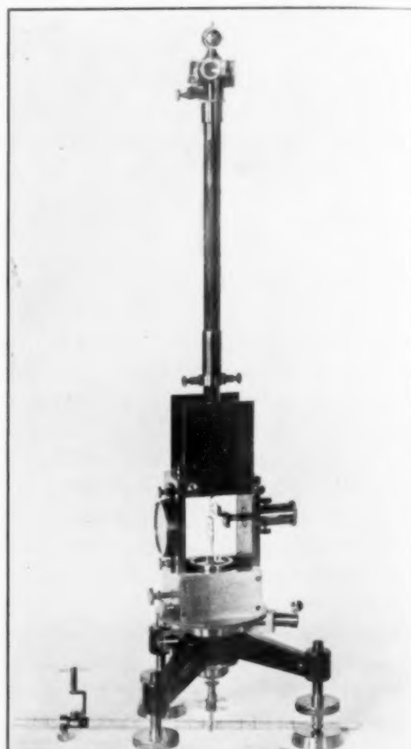


FIG. 4. MAGNETIC VARIOMETER

AS USED FOR RECORDING CHANGES IN COMPASS-DIRECTION

divided into a number of equal parts each corresponding to the selected time-unit, for example, in hours, in which case T_0 represents 0^h or midnight of the day and T_n the following midnight. Each hour is then represented at successive points 1/24, 2/24, 3/24, . . . of the length T_0T_n measured from T_0. On the lines at right-angles to this line at any of these points then may be plotted to any arbitrarily chosen scale the difference between this reference-line and the observed value at any time T_x. The phenomenon being one in which there is no change during the time represented, the graph representing it would be a straight line such as P_0P_n parallel to T_0T_n. For some phenomenon not constant during the time-interval being considered the line joining values plotted to our arbitrary scale on perpendiculars at the successive unit time-points to represent the changing values will form some regular or irregular curve such as P_0' P_x' P_n'. In an instrument to record change in compass-direction, consider Fig. 3 as a horizontal projection of a mirror attached to a magnetic needle, the latter so suspended at a point above the paper as to be free to rotate about its vertical axis at O. Suppose a source of light at L providing a horizontal light-beam directed toward the mirror; when the compass-direction changes through a small angle, the mirror rotates with it to some position as that shown by the heavy dotted line, and the reflection of the light-beam changes from OP_0' to OP_x'. A second mirror, fixed in position, causes a steady reflection of the light-beam to give a reference-line corresponding to T_0T_n. Now if a sheet of photographic paper, suitably protected from all light except the reflected beam, be so mounted as to have uniform motion either in the vertical plane or on a cylinder rotating on an axle AB, then as the compass-direction changes, the light-beam focused on the sensitive paper gives a photographic record as the paper shifts.

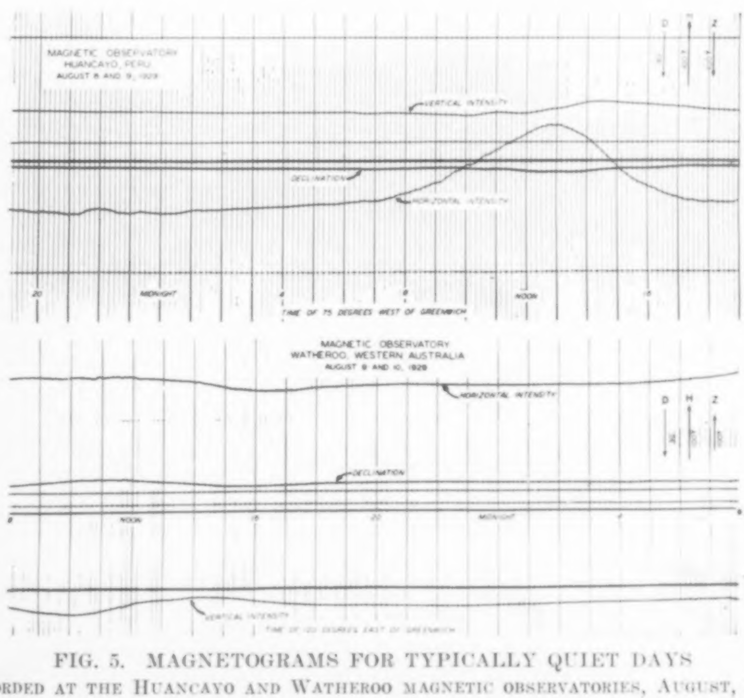


FIG. 5. MAGNETOGRAMS FOR TYPICALLY QUIET DAYS
RECORDED AT THE HUANCAYO AND WATHEROO MAGNETIC OBSERVATORIES, AUGUST, 1929

Upon developing this sensitized sheet we have a complete record of the movement of the compass-needle during the period. It is comparatively easy to determine by experiment or measurement of distances the length of the perpendicular to the reference-line of such a record for a unit angular motion as, for example, a single minute of arc or any other unit of measure. When such a method as outlined is translated into an actual instrument, as in Fig. 4, the optical and photographic recording devices intrinsically constitute substitutes for very long magnets which would be difficult to support so that they might swing freely with changes in the Earth's field. The length of the magnet in such a variometer is less than an inch, but with the optical arrangement this becomes theoretically infinitely long. Some actual photographic records of daily variations of the direction of the compass (magnetic declination) and of the forces acting in the vertical and horizontal planes are reproduced in Fig. 5.

Secular Variation

The usefulness for navigation at sea of magnetic direction or declination as indicated by the compass has stimulated and maintained interest in determining its value since the time of Columbus. Before the invention of chronometers it was thought that geographic position might be derived from knowledge of changes from place to place in magnetic declination and inclination. This led to the first systematic oceanic survey by the astronomer Edmund Halley in the Atlantic Ocean, during 1698–1700, on the sailing vessel *Paramour Pink*. As one result of his voyages the first isomagnetic chart was published. It showed lines at all points on which the compass-direction

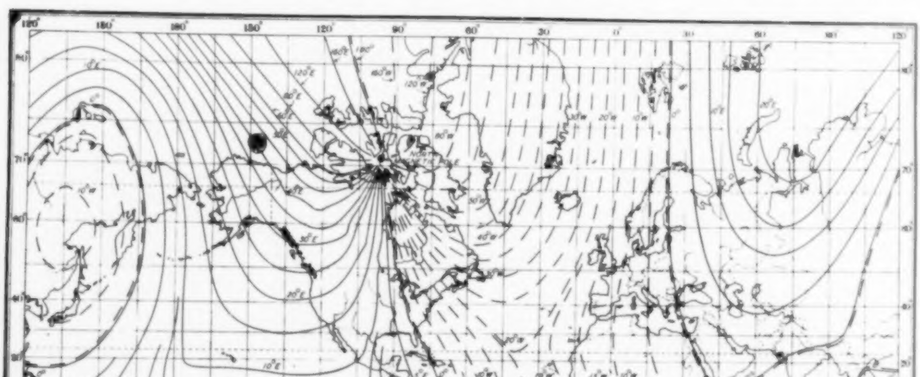


FIG. 6. CHART SHOWING LINES

ALONG WHICH MAGNETIC DIRECTION—DECLINATION—IS THE SAME FOR EPOCH 1930 BASED ON ISOGONIC CHART OF THE UNITED STATES HYDROGRAPHIC OFFICE

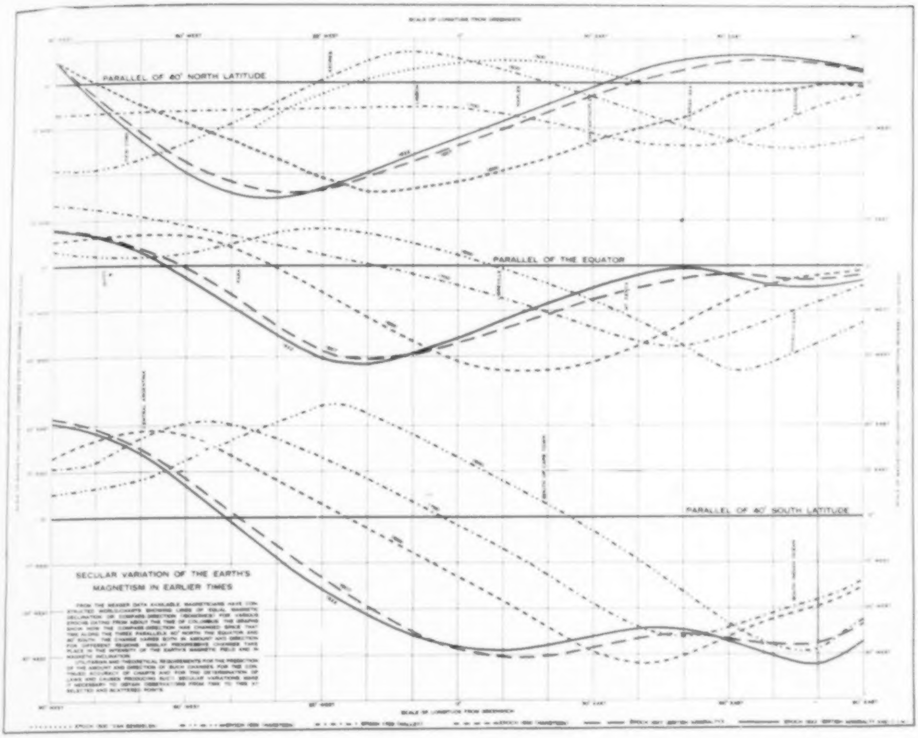


FIG. 7. GRAPHS SHOWING SECULAR VARIATION

IN DECLINATION OF THE EARTH'S MAGNETISM DURING 1500 TO 1922 FOR PARALLELS OF LATITUDE 40° NORTH, 0°, AND 40° SOUTH FOR LONGITUDES 90° WEST TO 90° EAST OF GREENWICH

differed from true north by the same angle, that is, lines of equal magnetic declination or isogonics. This chart and succeeding ones based on later data from time to time show the progressive changes in the position of these lines—changes known as secular variation. Fig. 6, for declination, is based on the latest isomagnetic chart published by the United States Hydrographic Office and applies for the epoch 1930. Its contrast with Halley's chart strikingly indicates the great accumulation of observed values during the past three centuries—an accumulation to which the Carnegie Institution has made large contributions since 1905 through its magnetic-survey operations on sea and land. The secular changes in the compass-direction in earlier times are indicated by Fig. 7, along several different parallels of latitude for various epochs.

Another picture of secular variation

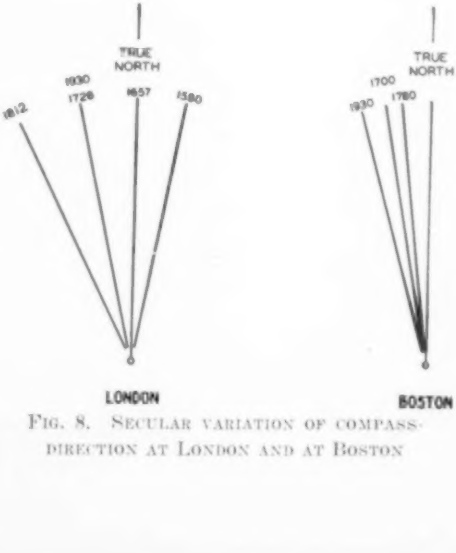


FIG. 8. SECULAR VARIATION OF COMPASS-DIRECTION AT LONDON AND AT BOSTON

utilizing observed compass-directions at London and at Boston is given by Fig. 8, showing the observed true bearing of the compass in different years. The importance of these changes in any practical use of the magnetic compass or needle may be realized by considering the observed data at London. There the magnetic needle pointed 11° east of north in 1580, changed gradually until it pointed 24° west of north in 1812, and since then has shifted eastward and now points only about 13° west of north. These results might be taken to indicate a complete cycle of change of about 500 years, but centuries more of observations are needed to verify such an indication.

For the purpose of illustration here, as well as later, let us conceive a thin, giant compass-needle about two miles long supported at its center by a pivot in which it is free to rotate, its north-seeking end taking at all times the direction of the Earth's magnetic field. The north end of this giant needle would move a little less than 100 feet for a change of one degree in direction or about one and one-half feet for a change of one minute of arc. At London its end would have moved westward from 1580 to 1812 more than 3,200 feet and then about 1,000 feet eastward to the present time. Here in Washington the annual change at present is such that the end of our giant needle would move because of it only about one-sixth of an inch per

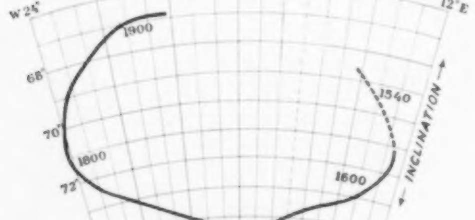


FIG. 9. SECULAR CHANGE IN MAGNETIC DECLINATION AND INCLINATION AT LONDON, 1540 TO 1900 (AFTER BAUER)

day toward the west, or a total of about five feet in the year. In the past 50 years this motion here would have totaled some 400 or 500 feet—a long city block—from the east.

A more illuminating graphical method developed in an early paper by Bauer to represent observed data is illustrated in Fig. 9. In this the magnetic needle is considered as being supported at its center so as to be free to turn in any direction in space. The changing position of a needle so mounted would show by the motion of its end secular variations both in the horizontal and vertical planes. At London such a needle would have described a conical surface in a clockwise direction. However, similar graphs for other stations in various parts of the world show different periods and amplitudes of this motion in space. So we may not assume a cyclic secular-variation of common period applying to the whole Earth. We must, therefore, dismiss as insufficient the popular notion that changes in compass-direction arise wholly or mainly from a shift in the position of the magnetic axis or of the magnetic poles of the Earth.

There is another interesting possible method by which secular-variation information may be extended to times more remote than those for which observations exist. When lava cools and freezes following a volcanic outburst, it takes up a permanent magnetization dependent upon the orientation of the Earth's magnetic field at the time. This, because of small capacity for magnetization in the Earth's weak field after freezing, may remain practically constant. If this assumption be correct, the direction of the originally acquired permanent magnetization can be determined by laboratory tests providing every detail of orientation of the mass tested is carefully noted and marked when it is removed. Samples of lava-flows of known date from Mount Etna back to 1284 have yielded fairly consistent data for mag-

netic declination and inclination, which apparently indicate a secular-variation period of about 750 years. Similar measurements have been made using lava-flows caused by eruptions in the fourth century B. C.; however, results depending upon measurements of this kind must be used with caution. There is another possible source of such data, although certainly even more speculative than the lava-flows. When vessels made of clay containing iron compounds are fired, they take on and retain a permanent magnetic condition and axis-direction depending upon their orientation in the Earth's field at the time of firing. These are negligibly influenced by later changes in the Earth's field. Determination of direction of the magnetic axis may then give some idea of the inclination of the Earth's magnetic field at the time the vessel was made.

During the past quarter century marked progress has been made in accumulating accurate and coordinated information which is beginning to shed light on the character of the changes in the magnetic elements particularly in those regions controlled by the more advanced nations. Any attempt, however, to arrive at a solution by examining what takes place within a limited area or during too short an interval of time is not only a hopelessly inadequate undertaking but is very likely to lead to erroneous suppositions. It is but another instance of the danger of drawing conclusions from half-truths so aptly illustrated by the often-quoted dispute of the

> . . . six wise men of Industan to learning much inclined
> Who went to *see* the elephant though all of them were blind.

Like the subject of that classical investigation, this is also of mammoth proportions, and like those seekers for truth, investigators of magnetic changes have given clear and valuable reports of what has come within their observation, each of which is essential to the construction of the complete picture. But as vision improves with the gradual accumulation of details, the complex character of the subjects begins to become apparent, and some real progress toward a reconciliation of the differences in first impressions may now be expected.

As stated, the scattered observations of declination run back over 300 years in a few limited localities. The collection of observations of inclination, due of course to its smaller practical utility as well as to the greater difficulty attending its measurement, is much less abundant. It is now almost exactly 100 years since Gauss first described a method of obtaining the absolute measure of the magnetic intensity, or the strength of the magnetic field. It is really only since that time that serious research in secular variation —one of the most fascinating and at the same time the most suggestive of the time-change problems of the Earth's magnetism—has been possible. One hundred years would be scant time for the changes of the slow-moving forces to produce effects sufficient for the purpose even if a complete record of the changes for that period were at hand. But the record is fragmentary at best, so that what is known of secular variation prior to renewed activity in the study of the subject manifested by the establishment of a considerable number of permanent and well-equipped observatories during the closing years of the past and the opening years of the present century is in general limited to a few restricted regions or to scattered localities.

Whatever may be found to be the source of that magnetization, any changes affecting it must take into consideration the nature of simultaneous changes appearing over the entire surface of the planet. There is no known means of "remote control," no method by which in a carefully equipped observatory or comfortable laboratory in an agreeable climate surrounded by the

FIG. 10. NON-MAGNETIC VESSEL *CARNEGIE*, ELBE RIVER, JUNE, 1928

comforts of home, a competent staff of investigators can apply themselves to the solution of this problem. Only a portion of the land surface of the Earth is peopled by nations whose intellectual and material equipment enables them to maintain magnetic surveys, and of the entire surface of the Earth but a minor fraction is of land. There are the backward lands, the jungles, and the deserts; there are the remote and all but inaccessible islands of the great oceans, and great expanses of the sea where no land is; there is the far frigid north and the frozen unknown of the farther south; such places must be included in a complete and homogeneous network of stations if a satisfactory picture of what is taking place is to be drawn. Such places can not contribute the information of themselves; expeditions must be organized by others who are able to go and seek it—not once, but repeatedly—since it is not a condition, but the changeableness of a condition which is sought. The phenomenon is not static but dynamic; it is not a still picture which we visualize once for all but a moving picture requiring repeated exposures, and each exposure meaning a long and arduous journey to parts where means of travel are primitive or entirely lacking, where oftentimes expensive expeditions must be organized and financed to secure pictures in the setting desired.

Often when a place has been revisited after the interval of years it is impossible to find and make a redetermination at the same position as that previously used, and a new point must be chosen. But as the time-changes sought are relatively very small, and as local displace-

ments often cause considerable differences due solely to peculiarities of the local geology, a new uncertainty is introduced to increase the difficulty of the task. Obviously the undertaking is too great for solution without the cooperation of scientific agencies of all countries. It is a satisfaction to record that there is a continually increasing number who are finding fruitful ways of contributing the details necessary to complete the picture.

As will be realized, the fascination—we may almost say romance—of the study of these data extends further to the efforts in their accumulation. Observational stations for the study of variations and perturbations must be located in out-of-the-way places even in populous countries to avoid those artificial disturbances arising from widespread use of electrical currents and devices. There is a lack of comfortable traveling conveniences in unexplored regions, despite the automobile, the airplane and the dirigible, though these are all combining to lessen the old difficulties and the time required in getting about.

In this magnetic survey to determine magnetic distribution and secular variation of the Earth's field the Department of Terrestrial Magnetism of the Carnegie Institution of Washington has done much. This extended on land to those countries and regions where there were or are no established magnetic-survey organizations, or where existing agencies for one reason or another welcomed cooperation. Thus, since 1905, almost 200 magnetic exploring expeditions to remote and little-explored regions were made. During 1905–29, also, an intensive magnetic survey of all oceanic areas was executed, for the first four years with the chartered brigantine *Galilee*, and during 1909–29 with the specially constructed, non-magnetic vessel *Carnegie* (Fig. 10). The latter vessel was unfortunately destroyed by a gasoline explosion and fire in Apia Harbor, November 29, 1929, during her last and seventh world-wide cruise. The number of magnetic distribution-stations of the Institution on land and sea now totals nearly ten thousand. During the past decade ten per cent. of these have been reoccupied for secular-variation data.

The secular-variation data being assembled, isomagnetic charts (Fig. 6) may be prepared for various epochs upon which to base theoretical discussions. In succeeding epochs because of secular variation, shifts of the isomagnetic lines have occurred. It is then

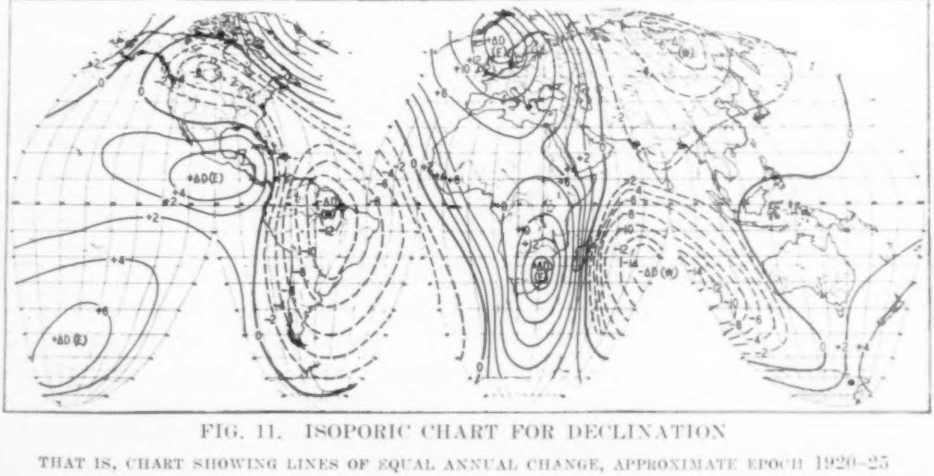


FIG. 11. ISOPORIC CHART FOR DECLINATION

THAT IS, CHART SHOWING LINES OF EQUAL ANNUAL CHANGE, APPROXIMATE EPOCH 1920–25

possible to join by a new set of lines those points past which the isomagnetics—as those of compass-direction or declination—have made the same progress. Thus, for instance, those places at which the declination has changed at the rate of one minute of arc a year, let us say to the eastward, are joined together. The same is done for changes of two minutes, three minutes, and so on up to the maximum rate of change of about one quarter degree, neglecting the immediate vicinity of the magnetic poles. Lines so drawn are called isopors or lines of equal marching. Only recently has it been possible to attempt drawing such isopors for the whole world with any degree of detail (see for example, the isopors of declination in Fig. 11). The picture resulting from these preliminary charts has presented the whole question of secular variation in a new light and has raised questions of broadest geophysical significance.

While it may be true that the rotation of the Earth with its magnetic field reaching out from it and surrounding it like a mantle constantly acted upon by radiations from the Sun and from the depth of space, subjects that field to a progressive precessional effect, what has long been suspected is becoming more and more apparent. A large part of the changes in the characteristics of the magnetic field has its origin not from influences impressed upon it from without, but arises from silent but titanic forces ceaselessly at work deep within the Earth itself. It must have been something of this sort which was in the mind of the Norwegian magnetician of the past century when he said that "the variations of the magnetic needle are a mute language revealing to us the changes perpetually going on in the interior of the Earth." And when we see the rise and fall of the rate of the secular change, the slow expansion and then the gradual retraction of the areas within which there have been excessive alterations in any of the magnetic elements, we realize there are still active changes going on in the Earth's interior.

On the isoporic chart for declination (Fig. 11) drawn for the approximate epoch 1920–25, a line showing no change over the period of a year runs from Nova Zembla off the northern coast of Russia, southward passing east of the Caspian Sea, thence continuing across Arabia and the island of Madagascar. East of this line the north end of the needle is pointing yearly farther west at a rate which increases slowly as the distance from the zero-line is increased, reaching a moderate maximum somewhere in eastern Siberia or Mongolia. The changes in the Indian Ocean are supposed to be larger than in Asia; this region is one where there are but scanty data available. However, to the west of that line of no annual change, over the greater part of Europe and extending somewhat into the Atlantic, there is a region of which we can speak with assurance, and one which presents a very interesting phenomenon. Numerous observatories have kept a continuous record of magnetic changes for nearly 30 years, some much longer, so that for that length of time the picture is for the most part complete. Proceeding westward from the Siberian border, we find the declination-isopors representing annual changes of one minute, two minutes, three minutes, and so on, packed quite closely together so that when we have reached Great Britain and the North Sea the annual rate of change in 1925 was nearly 13 minutes. The area having this large change is relatively small, so that the isopor takes the form of a small closed oval, surrounded by larger ovals successively representing the smaller changes. Along the northern part of Africa the changes are less rapid but in South Africa there is

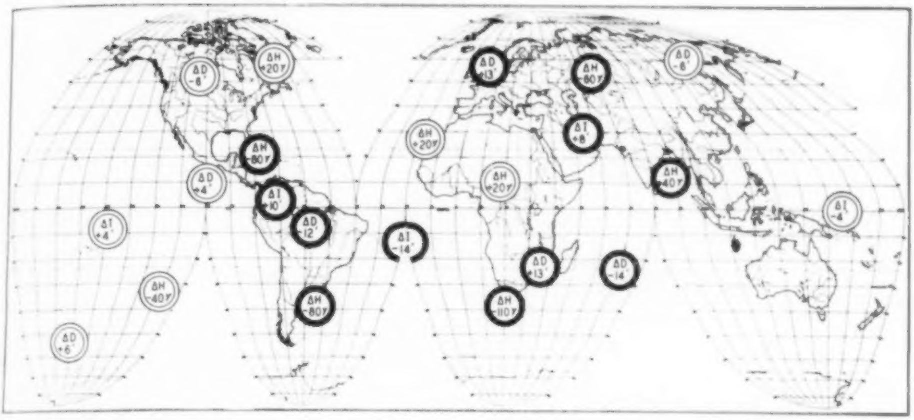


FIG. 12. DISTRIBUTION OF FOCI OF RAPID ANNUAL CHANGE OF THE MAGNETIC DECLINATION, INCLINATION AND HORIZONTAL INTENSITY, APPROXIMATE EPOCH, 1920–25

another focus of rapid change represented by concentric ovals on our isoporic chart. Unfortunately, there are no observatories at the present time in all of Africa south of Helwan near Cairo, so all we know of conditions there has been gleaned from occasional field observations.

But the foci of isopors are not permanent. The center of rapid change in western Europe has developed since the year 1900. If isopors are drawn for one-minute intervals, more than a dozen will be crossed at the present time in going from Ireland to the Ural mountains, whereas in 1905 scarcely more than one or two would have been crossed in the same distance. Now (in 1932) the zero-isopor is as described at about 60° east longitude; in 1905 it was in central Siberia at about 90°. So that while these ovals of our picture are moving outward from a center somewhere north of Scotland much as waves move in a pond from the spot where a stone has fallen into the water, the zero-line as a sort of shore-line against which these waves are beating has moved west to meet them. What the ultimate development of these figures will be we can only surmise, but there is reason to suppose that the dilation of these figures will be followed by a subsequent contraction. In eastern South America across a zero-isopor which passes from Labrador down the Atlantic past Cape Verde and St. Helena, there is a focus of opposite sign to those in Europe and South Africa, and the lines about this focus we know are moving inward. Do the lines move alternately inward and then outward, or do they continue to move inward until the focus disappears, perhaps to reappear elsewhere? We can not answer these questions until time has supplied the necessary knowledge, or until some geographical explanation has been found which will enable us to make a safe prediction.

The foci of isopors characteristic of the charts showing equal annual changes in declination are present also on the corresponding charts for the other elements. The distribution of these foci is noteworthy (Fig. 12). They are practically all found in the hemisphere containing the great land-masses with the intervening Atlantic Ocean. Such foci as are found in the Pacific hemisphere are of but moderate intensity and not well defined. This fact is doubtless significant, though what the significance may be we can only conjecture. This relation of large and rapidly changing

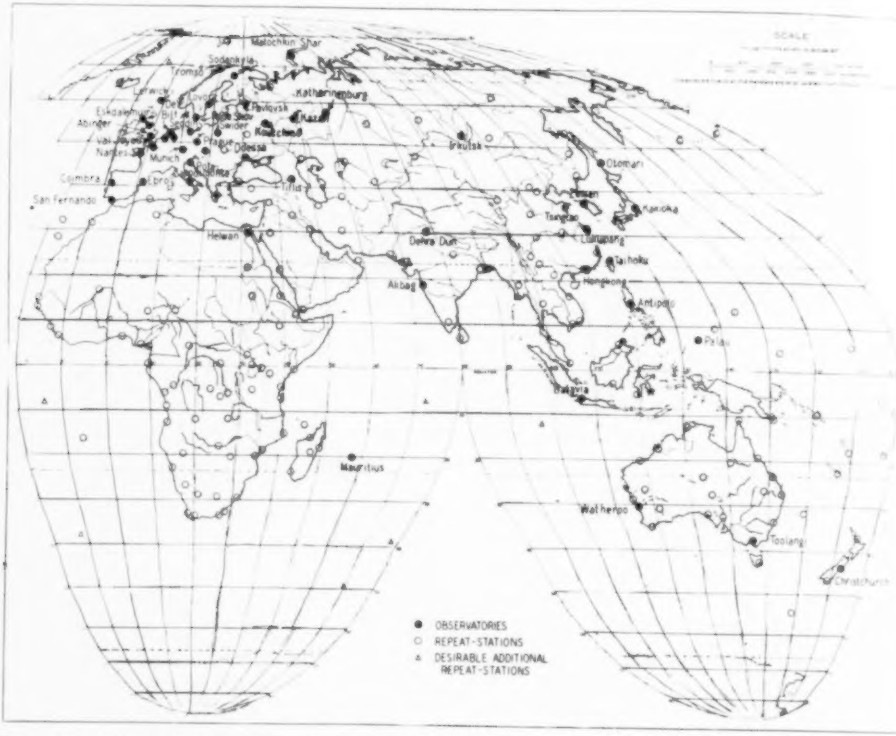


FIG. 13. DISTRIBUTION OF MAGNETIC OBSERVATORIES, REPEAT-STATIONS, AND DESIRABLE REPEAT-STATIONS IN EUROPE, AFRICA, AUSTRALIA AND INDIAN OCEAN

rates of change of the intensity and direction of the magnetic field to the surface structure of the Earth can scarcely be accidental; it is natural to suspect that there is a causal relationship existing between crustal or subcrustal movements and these magnetic manifestations. Perhaps there are changing mechanical stresses, or possibly a changing distribution of internal heat, which in turn affects the direction or magnitude of subterranean electric currents. The phenomenon certainly emphasizes the warning of Maxwell that we must not suppose the inner history of our planet has ended.

The following conclusions have been drawn from the extended mathematical analyses in the Carnegie Institution's Department of Terrestrial Magnetism of data for mean epochs 1842, 1882, and 1922. The main cause of the secular variation arises from a system of forces embedded in the Earth. Secular variation is caused not only by a change in direction of magnetization but likewise by a change in the intensity of magnetization. The average annual decreases in magnetic force have been larger for the southern, or water, hemisphere than for the northern, or land, hemisphere, while the average equivalent intensity of magnetization over land areas is somewhat larger than that over oceanic areas. There appears to be a small decrease each year in magnetization—approximately one fifteen-hundredth part. The Earth's total magnetic field at any one time is apparently attributable to the extent of

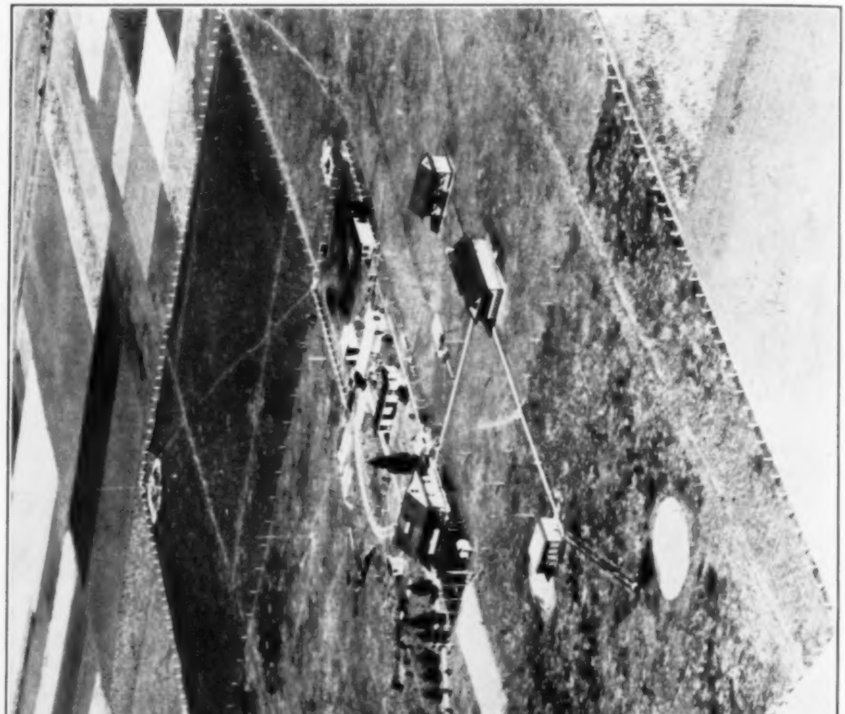
about 94 per cent. to an internal magnetic system and to an extent of about 6 per cent. to external systems.

Diurnal-variation

The next important time-change—the solar diurnal-variation—in the Earth's magnetic field was discovered in 1722, at London, by a mechanician and clock-maker named Graham. It is stated that at Louveau, Siam, in 1682, experiments in the presence of the King showed the compass-direction different on seven different days; probably these were made at different times of the day and thus were really the first observed indications of diurnal variation.

The length of time required for collecting the necessary data for the study of the diurnal variation repeated day by day, is more commensurable to man's lifetime and that problem can, therefore, be studied at magnetic observatories within a reasonable time with much more detail than can the slow secular variation. Magnetic research has already yielded correspondingly more definite results in this aspect of the subject and has shown promising lines for future work. And while on one side the search

Fig. 14. Distribution of magnetic observatories, repeat-stations, and desirable repeat-stations in North America, South America and Pacific Ocean



—*Courtesy of Johnson-Shippee Expedition*

FIG. 14A. SITE AND BUILDINGS OF HUANCAYO MAGNETIC OBSERVATORY FROM THE AIR, APRIL, 1931

for the explanation of the main part of the Earth's magnetic field and its secular variation is hampered by the fact that we know only one planet, namely, our own, and that we have to put up with those irregularities in its crust, that distribution of land and sea which we find upon it, we can on the other side collect data for the diurnal variation for very many days and utilize the natural differences in season, in magnetic disturbance, in sunspot-numbers for testing theories and drawing conclusions.

The world-distribution of existing magnetic observatories is shown by the black dots on Figs. 13 and 14; the open circles and the small triangles on these charts indicate desirable repeat field-stations for the determination of secular variation. From the first chart, showing Europe, Asia, Australia, Africa, and the Indian Ocean, we see how great a majority of the observatories are in Europe. It is especially noteworthy that on the whole of Africa there is only one existing magnetic observatory and that in the extreme northeastern part. When it is recalled that several foci of large secular change are located in Africa, the importance of additional magnetic observatories there is apparent. The second chart shows the distribution of existing observatories in North and South America and in the Pacific Ocean. Such observatories and laboratories have, indeed, been established by forward-looking and scientific-minded nations, and they are an indispensable source of data which the solutions of magnetic questions require. Our own country, through the work of its Coast and Geodetic Survey, has contributed much, especially in the past thirty years through its magnetic surveys of the United States, its territories, and coastal waters, and through the maintenance of five well-distributed observatories. The Institution also established and maintains two magnetic observatories, the one near Watheroo, Western Australia, and the other near Huancayo, Peru (Fig. 14A). The latter is uniquely located on the magnetic equator at an elevation above sea of 11,000 feet, while the former adds a much-needed station in the southern hemisphere.

The diurnal inequality varies with the season of the year, the range of this inequality being greater in summer than in winter. As one goes from temperate zones to the frigid or to the torrid zones, these summer and winter inequalities present widely differing features. The extent to which such an inequality varies throughout the year is readily seen by the graphs in Fig. 15. It will be immediately apparent that diurnal variation in its main features progresses according to local mean time. Thus this variation is connected with the Earth's rotation and, as its major tendency follows the apparent motion of the Sun, it may be presumed that the Sun is an important factor in this daily phenomenon. This variation also is the first indication that the Earth's magnetism responds to outside influences which find their origin in solar activity and act upon the upper regions of the atmosphere. Fig. 16 also indicates how this diurnal variation changes with season, the greatest ranges always occurring in the summer months.

Here in Washington the north end of the compass-needle on a magnetically-quiet day starts swinging eastward, beginning with sunrise, continuing so until some time between 8 and 9 o'clock, when it swings rapidly towards the west until between 1 and 2 o'clock and then returns to its first position. The end of our giant two-mile needle would have an extreme motion in the course of daylight of about 10 to 15 feet; during the night hours its motion would be much slower and much smaller.

The diurnal variation of declination at Watheroo for the year 1930 by seasons yields three curves (Fig. 17) exhibiting

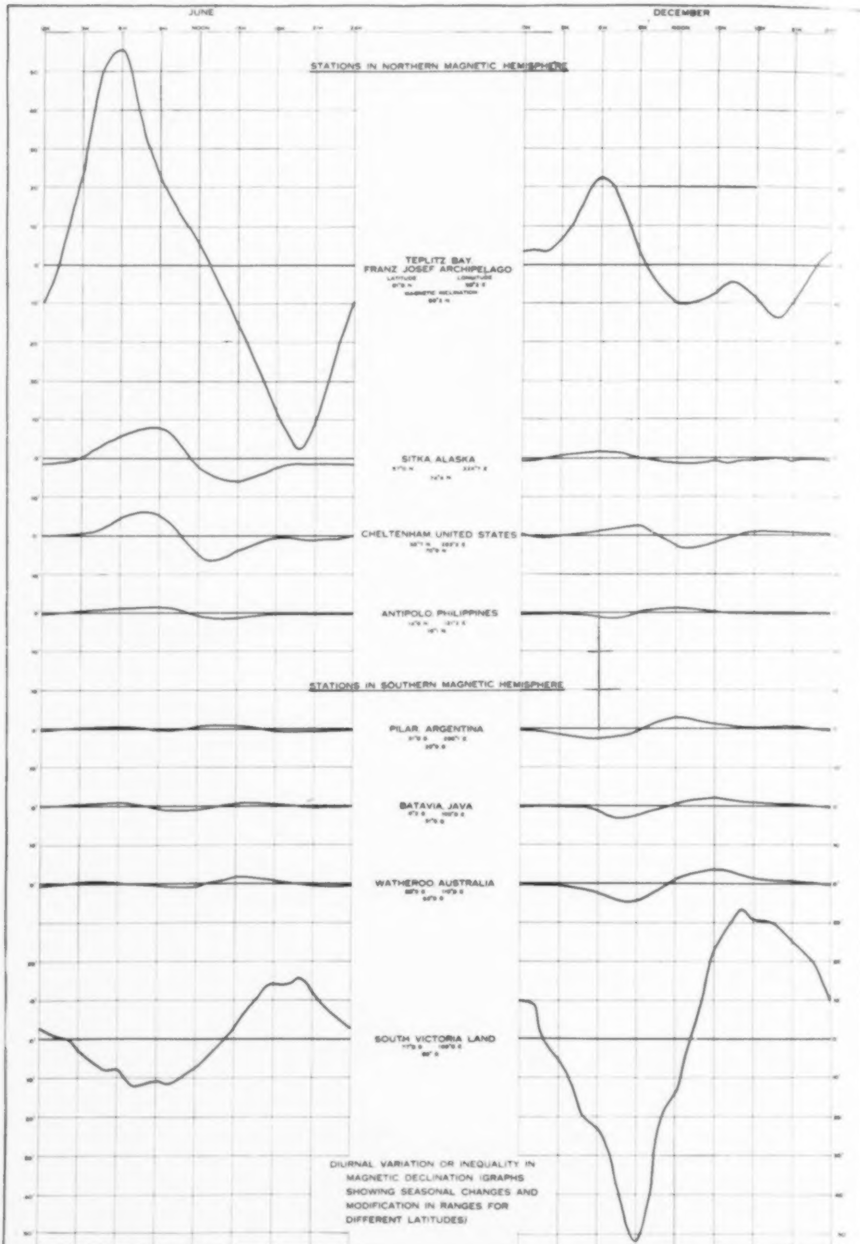


FIG. 15. DIURNAL VARIATION IN MAGNETIC DECLINATION

SHOWING CHANGES FOR DIFFERENT SEASONS IN DIFFERENT LATITUDES—UPWARD MOTION OF THE CURVES INDICATES INCREASING EAST DECLINATION OF THE NORTH-SEEKING END OF THE NEEDLE

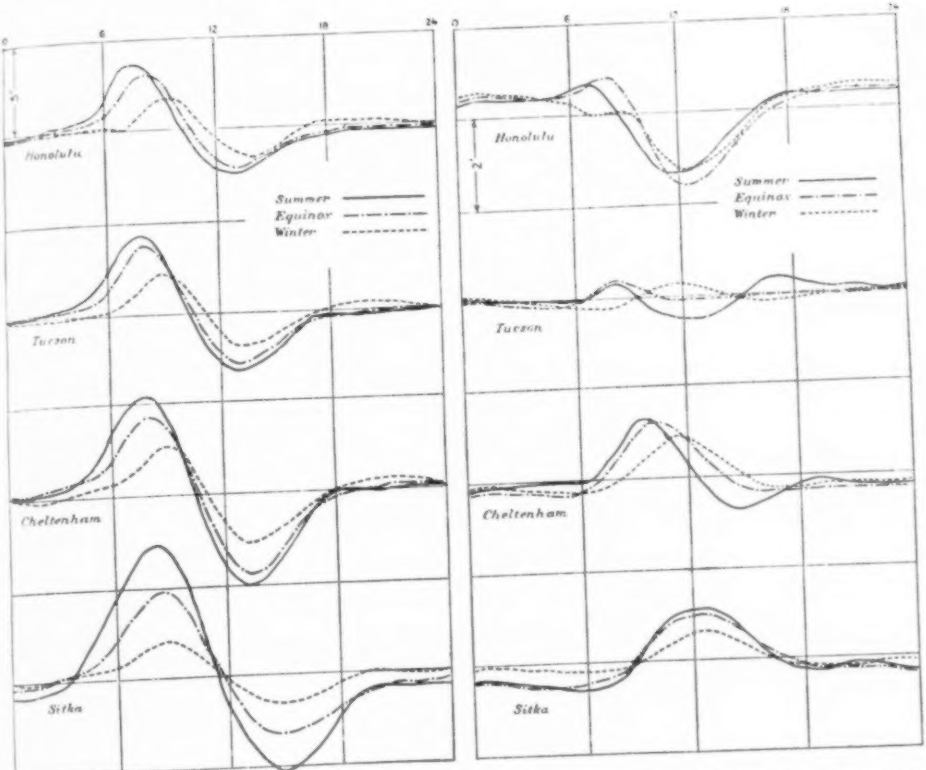


FIG. 16. DIURNAL VARIATION OF MAGNETIC DECLINATION (LEFT) AND INCLINATION AT HONOLULU, TUCSON, CHELTENHAM AND SITKA OBSERVATORIES FOR SUMMER, EQUINOX AND WINTER (AFTER U. S. COAST AND GEODETIC SURVEY)

the "southern" type of variation which characterizes a magnetic observatory situated at about 30° south, where the focus of the external electrical current-system causing diurnal variation passes approximately overhead daily. The variation is greatest at the December solstice and least at the June solstice due to the fact that the ionization produced by the Sun is greatest or least respectively over the southern hemisphere at those seasons. At Huancayo, on the magnetic equator, the corresponding graphs (Fig. 18) show the variation at the December solstice, when the Sun is actually south of Huancayo, is of the south temperate type, while when the Sun is over the northern hemisphere the variation is of the north equatorial type. This is an excellent indication of the changes which take place in the overhead current-system from season to season. Instead of moving northward or southward with the seasons as one might expect, this series of curves indicates that the southern current-circuit or the northern current-circuit expands according as the Sun is over the southern or northern hemisphere, so that during the northern summer Huancayo is included in the edge of the northern circuit while during the southern summer it falls well within the southern circuit. Similar phenomena are exhibited by the diurnal variations at Batavia and Apia, other observatories near the magnetic equator.

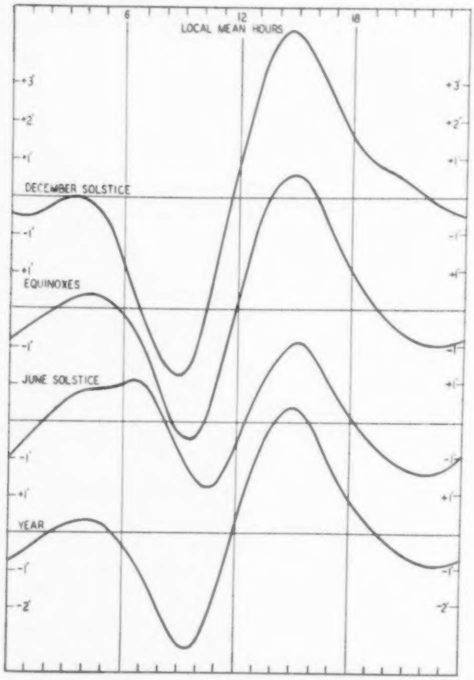


FIG. 17. MEAN SEASONAL AND ANNUAL DIURNAL-VARIATION IN MAGNETIC DECLINATION AT WATHEROO MAGNETIC OBSERVATORY, 1930

SMALLER PERIODIC VARIATIONS—LUNAR-DAY AND ANNUAL

Besides the ordinary diurnal variation there is another, small and quite systematic, namely, that associated with the Moon's position.

We have seen in several figures the average daily influence of the Sun on the magnetic force as revealed by the 24 average hourly mean values for a number of days giving the systematic changes in the course of a solar day, from midnight to midnight, that is, from one lower transit of the Sun to the next. In the same way, we can speak of a lunar day, reckoned from one lower transit of a moon to the next. This interval is, on the average, 50 minutes longer than a solar day; for convenience, we divide it into 24 lunar hours of equal length. By combining the magnetic values for each corresponding lunar hour of a large number of days, we obtain the influence of the Moon on the Earth's magnetic field, that is, the lunar diurnal-variation. The magnitude of the lunar variations is less than one tenth of the solar and can be derived only by careful analysis from very many observations.

While the lunar variation is too small to have practical interest for navigational purposes, it is very important for the investigation of the highest layers of the atmosphere, where these magnetic variations are produced. The simple nature of the lunar variations, the double wave, indicates their tidal origin, that is, their relation to the same forces which cause the familiar regular rise and fall of the water in the ocean and which produce similar and even more regular movements in the atmosphere.

The full significance of the lunar variation is brought out if we calculate it separately for the different phases of the Moon, which are shown in Fig. 19, for

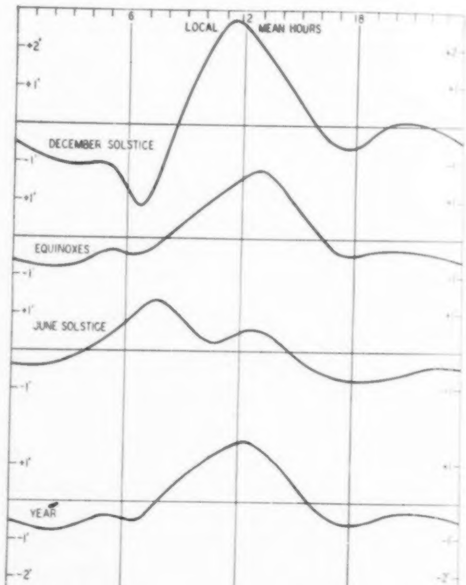


FIG. 18. MEAN SEASONAL AND ANNUAL DIURNAL-VARIATION IN MAGNETIC DECLINATION AT HUANCAYO MAGNETIC OBSERVATORY, 1930

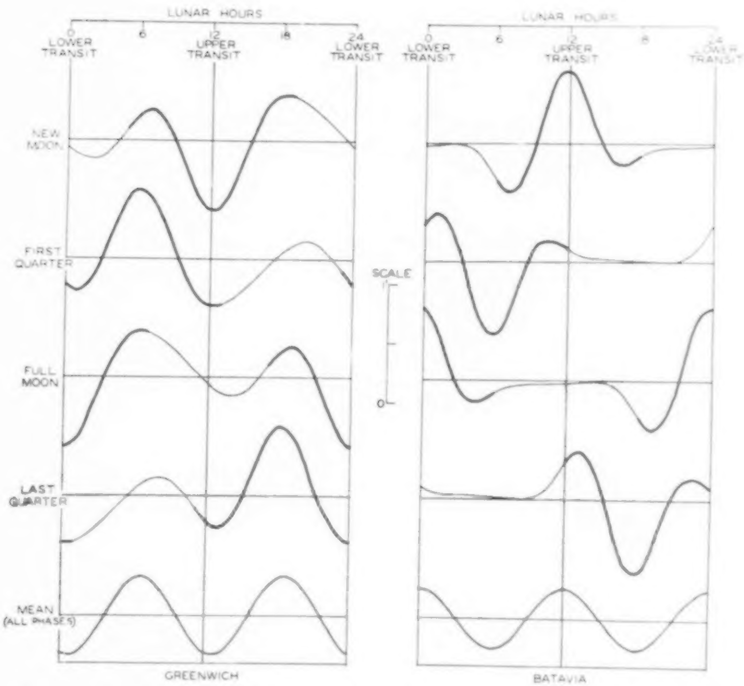


FIG. 19. LUNAR DIURNAL-VARIATION EAST MAGNETIC DECLINATION IN SUMMER

data from Batavia and Greenwich. These curves are based on 63 years of observations, or over 180,000 hourly observations in the four summer months May to August. The greater variation is in daylight hours, this effect of the tidal movements being enhanced by higher ionization, higher conductivity of the atmosphere. From our knowledge of the tidal movements and of the lunar magnetic variations, we can infer the change of ionization in the course of the solar day, and also the different physical state of the atmosphere in the different seasons, in different stages of the sunspot-cycle, and at different degrees of magnetic disturbance. Note that the Batavia and Greenwich curves have opposite phase—Batavia a maximum at transit, Greenwich a minimum—because they are situated on opposite sides of electric current-system in the upper atmosphere which produces them.

It is very likely that lunar variations originate in even higher layers of the atmosphere than the solar variations, because they are so extremely sensitive to changes in magnetic activity as shown in Fig. 20. In Batavia the lunar variation is just as regular on disturbed days as on quiet days, but the range is tenfold as great. The location of an observatory is an important consideration affecting the evidence it provides for the study of this phenomenon. The Institution's observatories at Watheroo and Huancayo are key stations in an investigation on lunar diurnal-variations, the former being in the center of the current-system producing it and the latter on the magnetic equator.

When monthly values of compass-direction are corrected for the progressive secular change, they show a small variation with the year as a period. This, known as the annual variation, is a cyclical change and should not be confused with the annual change which

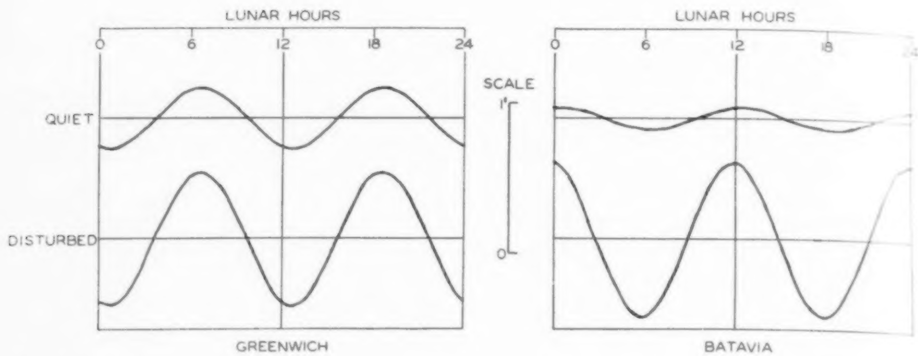


FIG. 20. LUNAR DIURNAL-VARIATION EAST MAGNETIC DECLINATION ON MAGNETICALLY QUIET AND DISTURBED DAYS

means the change in one year due to secular variation. This annual variation is a minute quantity and for stations in North America shows a total range of about one minute of arc. Thus the ends of our giant compass-needle at Washington would oscillate because of this variation during the present year through little more than one foot. So far as investigated, the cause of this variation appears to be outside the Earth.

A study of the time-changes affecting the magnitude and direction of the forces controlling the movement of the compass-needle has shown us that both the Sun and the Moon exert a subtle influence over them, and it is but natural to infer that a similar influence emanates from the planets or from the distant stars. Such a possibility has not been overlooked but so far there is no positive evidence from available data that anything of that kind exists.

Regular and Irregular Variations and Magnetic Activity

There are other time-changes of quasi-regular and of irregular types. These are associated with what we call the Earth's magnetic activity or, let us say, its general state of magnetic rest or magnetic unrest.

This magnetic activity at a given station, during any interval, may be defined as a measure for the frequency and intensity of marked irregular deviations—magnetic storms—for example, from the normal diurnal variation, in that interval. There are many ways in which such a definition may be numerically expressed. The simplest and now most generally used is the international characterization. In this every observatory, from inspection of the character of its photographic records, assigns to each 24 hours between successive Greenwich midnights a "character-figure" on a scale 0–1–2. The character "0" applies to quiet, "1" to moderately disturbed, and "2" to greatly disturbed days. The adopted daily values are the averages for all collaborating observatories, the number of which increased from 30, when this measure was begun in 1906, to about 45 in 1932.

A more detailed method of measuring activity is that called the *u*-measure. This depends upon the interdiurnal variability, that is, the average difference regardless of sign, in the force directing the compass between successive daily means.

During days of character 2 our giant two-mile needle will have violent oscillations causing its north end to move

through as much as 100 feet here in Washington. At stations in polar regions, these disturbances are more violent because of the proximity of the magnetic poles. Actual records for Arctic stations have been obtained at times which would indicate that the north end of our giant needle would have shifted during such disturbance 20° to 30°—equivalent to a total displacement of its end through distances of about 2,000 to 3,000 feet. When it is borne in mind that such deflections may occur in a few minutes of time, the agitation of the Earth's field during such disturbances is readily realized. All intermediate stages between very quiet and extremely disturbed conditions exist.

Magnetic storms may be classified as having origin due (1) to changes occurring in the regions about the Earth, (2) to changes within the Earth, and (3) to changes within or external to the Earth and with center of field of action at times stationary but generally moving from place to place. Storms of the first type are simultaneous over the Earth. Frequently they are initiated by a sudden sharp shift following comparatively quiet or normal conditions and for this reason are called "sudden-commencement" disturbances. Sudden commencements seem always of an oscillatory character, and in general a tendency to oscillation and continual unrest is one of the most outstanding features. Fig. 21 reproduces the records of disturbed days at the Huancayo and Watheroo observatories, December 3–5, 1929. Fig. 21A shows records obtained on the same days at Little America, where the Institution cooperated with the Byrd Antarctic Expedition in maintaining a temporary magnetic observatory.

Storms of the second type are sometimes associated with great volcanic out-

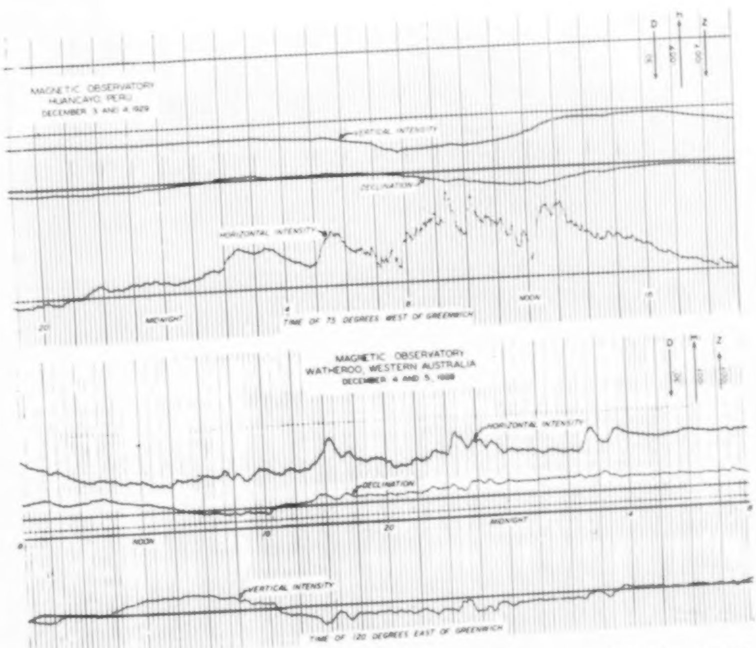


FIG. 21. MAGNETOGRAMS FOR TYPICALLY DISTURBED DAYS AT THE HUANCAYO AND WATHEROO MAGNETIC OBSERVATORIES, DECEMBER, 1929

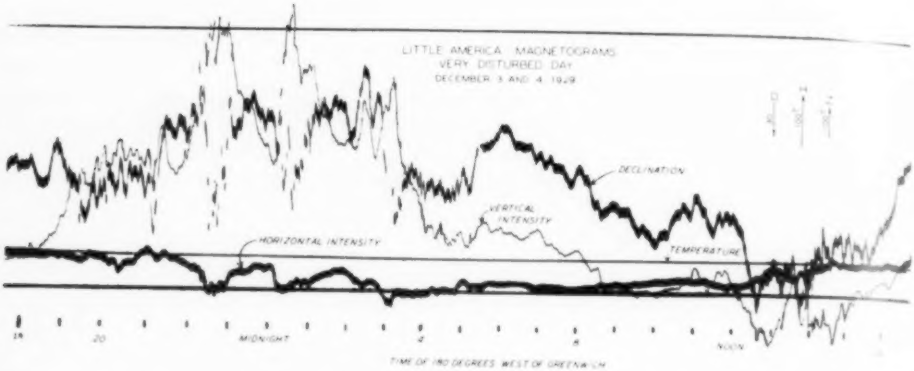


FIG. 21A. MAGNETOGRAM FOR TYPICALLY DISTURBED DAY AT LITTLE AMERICA, ANTARCTIC CONTINENT, DECEMBER, 1929

bursts as was the case for the eruption in Martinique in May, 1902, evidenced as world-wide by the magnetograms of many observatories. Fig. 22 reproduces records of the compass-directing magnetic force at 21 observatories. The third type is usually represented by a rather slowly developing "bay" on the record extending over a half-hour or somewhat more.

Thus disturbed or quiet magnetic conditions nearly always affect the whole Earth simultaneously. The possibility of any connection between disturbances of the Earth's magnetic field and the weather is excluded since weather is so distinctly local and so different all over the world. But polar lights—the aurorae—are always seen in polar regions when magnetic storms occur. See Figs 23, 23A and 23B for photographs of auroral displays of several types off Siberia. Since the height of polar lights has been determined to be in no case less than 50 miles above the ground, the conclusion is drawn that the magnetic variations and disturbances also have their origin in electrical phenomena taking place at least at greater heights in the atmosphere. This has been confirmed in every respect and the study of the magnetic variations is one of our main sources of information about the constitution of and the phenomena in these outermost and inaccessible regions of the atmosphere.

It was demonstrated in 1908 by Hale at the Mount Wilson Observatory of the Carnegie Institution that the Sun possesses a total magnetic field perhaps 50 times that of the Earth. But a field of that intensity is far too weak to make its magnetic influence felt at the Earth, 93,000,000 miles distant. It is much more probable that solar influences on the Earth's magnetism are connected with enormous streams or clouds of particles, atoms, ions, and electrons ejected from the active regions of the Sun, which travel through space and from time to time reach the Earth after one or two days, impinge its atmosphere, causing magnetic storms, which often disturb electrical communications. These particles, like the wave-radiations mentioned above, do not reach the Earth's surface but are stopped by the air before they come lower than 50 miles and cause inductively some of the observed effects in currents in the air and in the Earth. Thus one may conceive magnetic disturbance-features as the result of "messages from space."

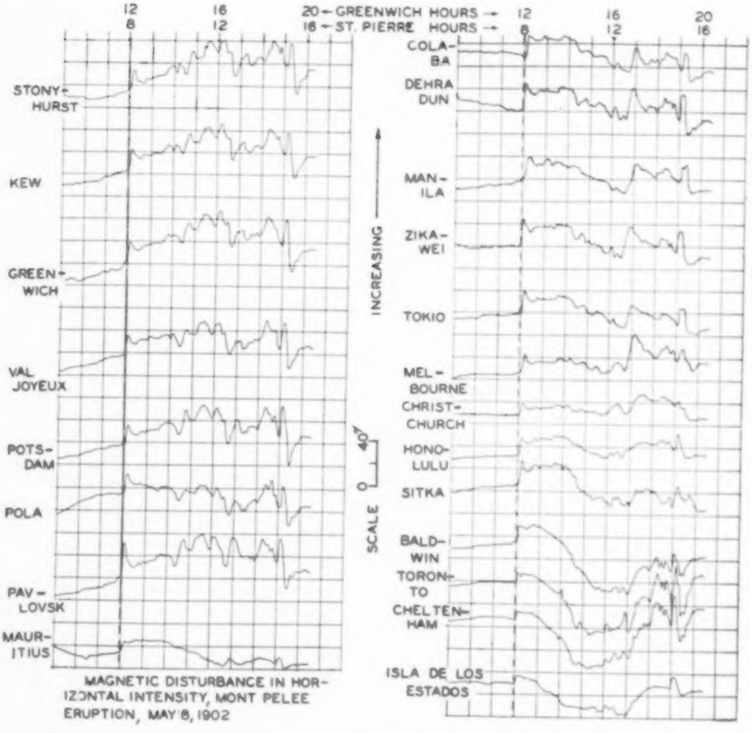


FIG. 22. SUDDEN-COMMENCEMENT MAGNETIC DISTURBANCE OF MAY 8, 1902, BEGINNING AT TIME OF MONT PÉLÉE ERUPTION

The regular daily magnetic variation apparently is the effect of other radiations from the Sun, which are absorbed in the highest levels of the air, and which make these layers electrically conducting. These conclusions drawn many years ago from magnetic observations became more important after the invention of wireless telegraphy, because with them we may explain why wireless waves are bent around the Earth along these same conducting layers.

The range of diurnal variation varies with magnetic character—a feature brought out in Fig. 24. Statistical studies have led to the identification of three phases in the progress of a disturbance, (1) strengthening of the ordinary diurnal movement according to local time, (2) everywhere a similar but unequal course according to universal time, and (3) a periodic damped wave dying out in the post-perturbation.

Magnetic activity provides one of the means of determining another time-change, namely, that of an 11-year period apparently agreeing with the well-known period in sunspot-frequency (Fig. 25). Latest investigations have shown, however, that solar activity as indicated in its reflected effect in the magnetic field is not completely or always represented by sunspottedness or other phenomena which astrophysicists observe on the Sun's surface; magnetic observations apparently reveal distinct solar influences of another kind and add in this way to our knowledge of solar physics.

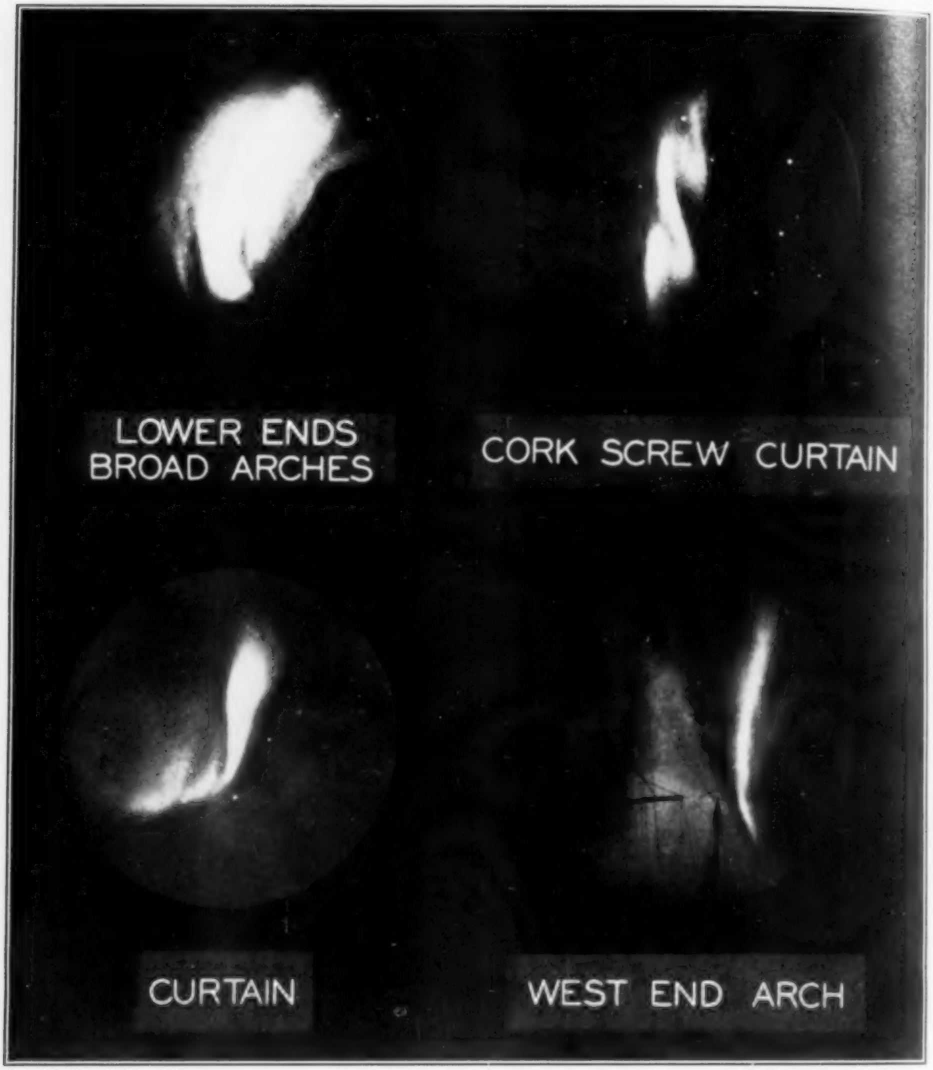


FIG. 23. TYPES OF AURORAL LIGHTS FROM PHOTOGRAPHS MADE OFF THE NORTH COAST OF SIBERIA

As the Earth revolves about the Sun during the year there are corresponding fluctuations in magnetic activity, the maximum or crest occurring during the equinoctial months of March and September, and the minimum or trough in the solstitial months of June and December. This annual variation of magnetic activity, shown by Fig. 26, was deduced from the examination of 59 years of observations, 1872–1930, at a number of observatories. The graphs result from grouping the data in thirds according to high, average, and low activity.

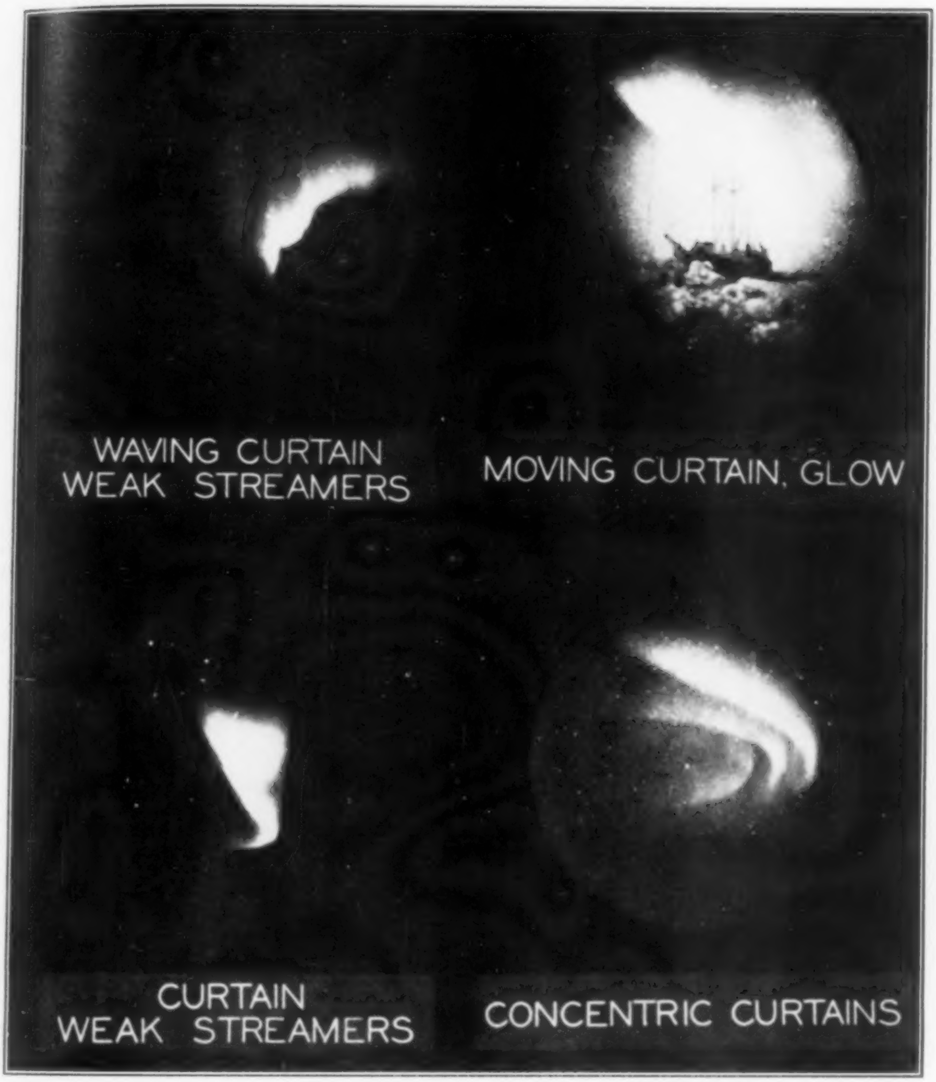


FIG. 23A. FURTHER PHOTOGRAPHS OF AURORAL LIGHTS

Another time-change related to magnetic disturbances is shown by Fig. 27, for an interval chosen at random, the consecutive averages of magnetic force over 24-hour intervals centered at 0^h, 6^h, 12^h, and 18^h Greenwich mean time for three widely separated stations—Seddin (near Potsdam, Germany), Huancayo (Peru), Watheroo (Western Australia). The three curves are strikingly similar showing typical depression during a disturbance followed by gradual recovery to normal value afterwards. Obviously the *u*-measure which is derived from

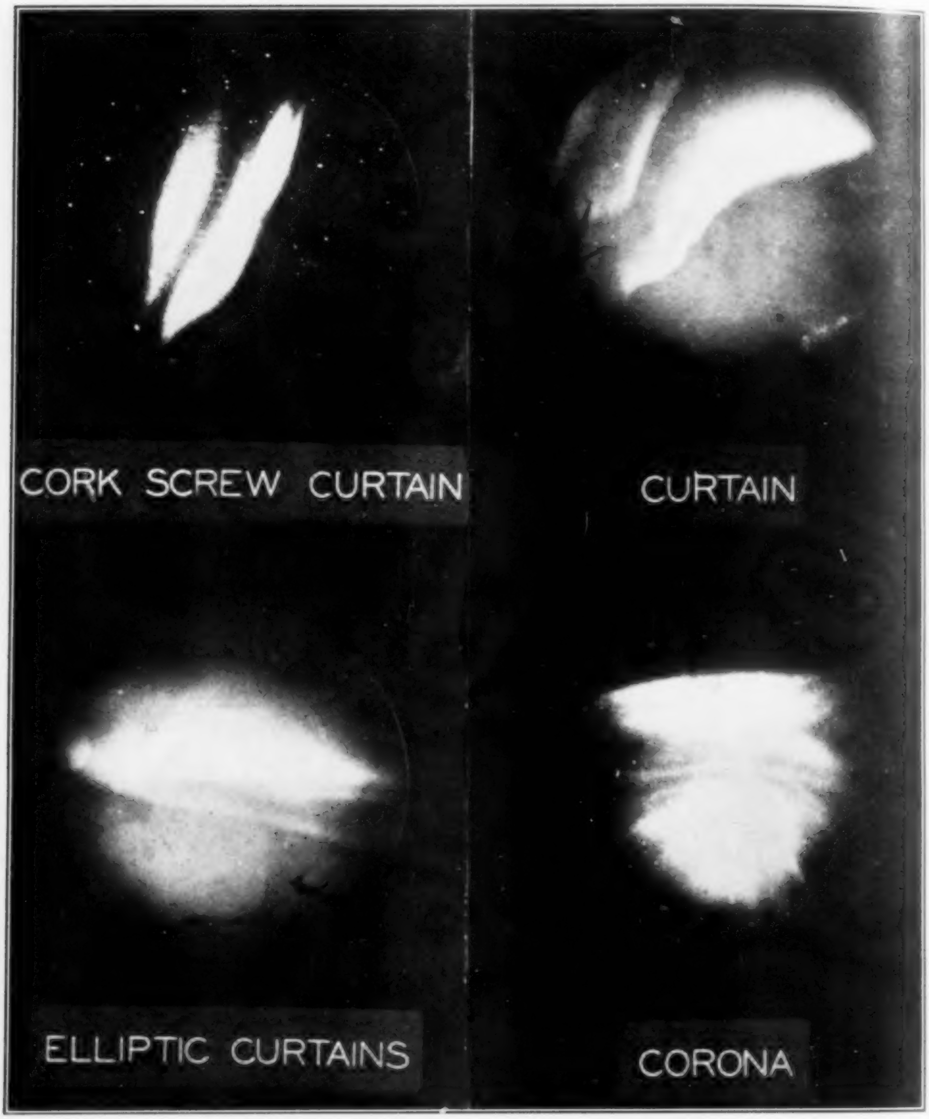


FIG. 23B. FURTHER PHOTOGRAPHS OF AURORAL LIGHTS

such systematic changes must be representative of the world-wide magnetic activity.

PULSATIONS

Another type of irregular disturbance is that known as micropulsations first noted by Eschenhagen and which appear to be of about the same magnitude at different locations on the Earth. These are of very short periods such as 5 to 15 seconds of time. It has been proposed (Störmer, 1906) that these short-period

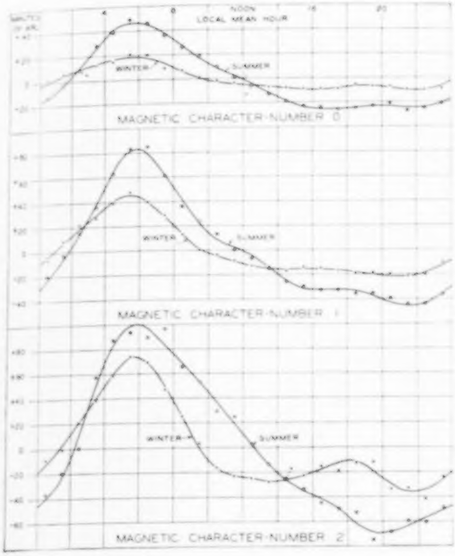


FIG. 24. CORRELATION BETWEEN DAILY VARIATION OF COMPASS-DIRECTION AND MAGNETIC ACTIVITY AT CAPE CHELYUSKIN, SIBERIA, OCTOBER, 1918, TO AUGUST, 1919

and small-amplitude pulsations may be explained in the world-wide sense as the electromagnetic effects of clouds of electrically charged particles moving in periodic orbits around the Earth. On the other hand, there are recorded at observatories in regions of comparatively limited area a giant type of pulsation with periods of as much as one and one-half to two minutes of time and ranges from 10 to 20 times as great. At the present time there is apparently such an area near Scandinavia. Fig. 28 shows records of giant pulsations obtained September 10 and 12, 1930, at Abisko, Swedish Lapland, and September 12, 1930, and September 19, 1931, at Tromsö, Norway. Tromsö is something over 90 miles north of Abisko. At two other observatories 215 and 370 miles, respectively, from Abisko the ranges recorded were considerably reduced, while they were found to be very minute or negligible at observatories distant about 1,000 miles or more. On account of the relatively local character of these giants, they can hardly be explained as suggested above for the normal small-amplitude pulsations. They may, therefore, reasonably be ascribed to peculiar currents now prevailing in the atmosphere above the northern part of Scandinavia or to a deeper penetration at times into the atmosphere there of Störmer's electrified "flying clouds." That such giant micropulsations are of local cause is indicated also since at other observa-

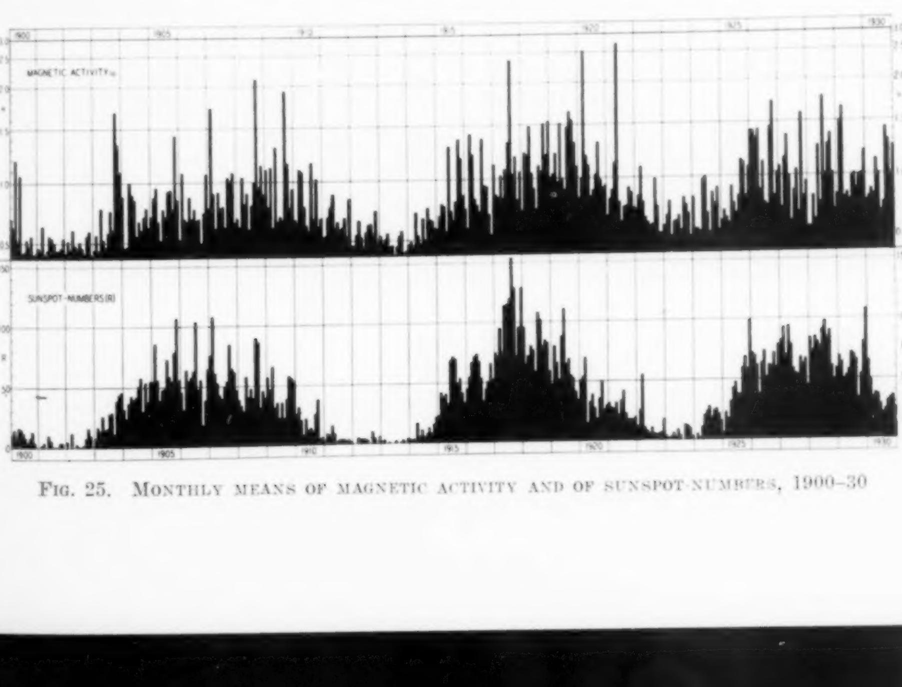


FIG. 25. MONTHLY MEANS OF MAGNETIC ACTIVITY AND OF SUNSPOT-NUMBERS, 1900–30

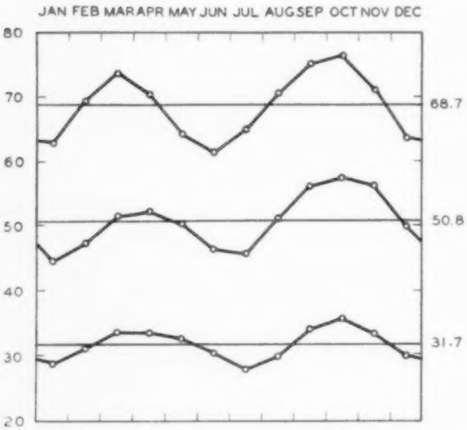


FIG. 26. ANNUAL VARIATION OF MAGNETIC ACTIVITY, 1872–1930, AVERAGED ACCORDING TO HIGH, AVERAGE AND LOW ACTIVITIES

tories they may be occasionally recorded for a period of years and then cease. Thus Professor Nippoldt at Potsdam, Germany, states that giant micropulsations "went to sleep" in 1903 and have since been very rare there.

CONCLUSION

This complexity of the magnetic time-change phenomena has baffled attempts at theoretical explanations or hypotheses although long the field of able and enthusiastic investigators. We may hardly hope in our time to lay down a general theory which will explain the multitude of observed facts or permit us to foretell with any precision future changes. Despite this, magnetic observations have already added materially to our knowledge of the Earth's interior, particularly to some of the geological features of its crust. Thus secular-variation changes within the crust indicate an interior

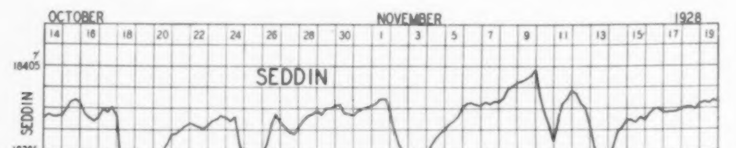


FIG. 27. TYPICAL DEPRESSION (POST-PERTURBATION EFFECT) FOLLOWING MAGNETIC DISTURBANCES AS SHOWN BY DATA FROM THE SEDDIN, HUANCAYO AND WATHEROO OBSERVATORIES, OCTOBER 14 TO NOVEMBER 19, 1926, WITH GRAPH OF INTERNATIONAL CHARACTER-FIGURES FOR THE SAME PERIOD

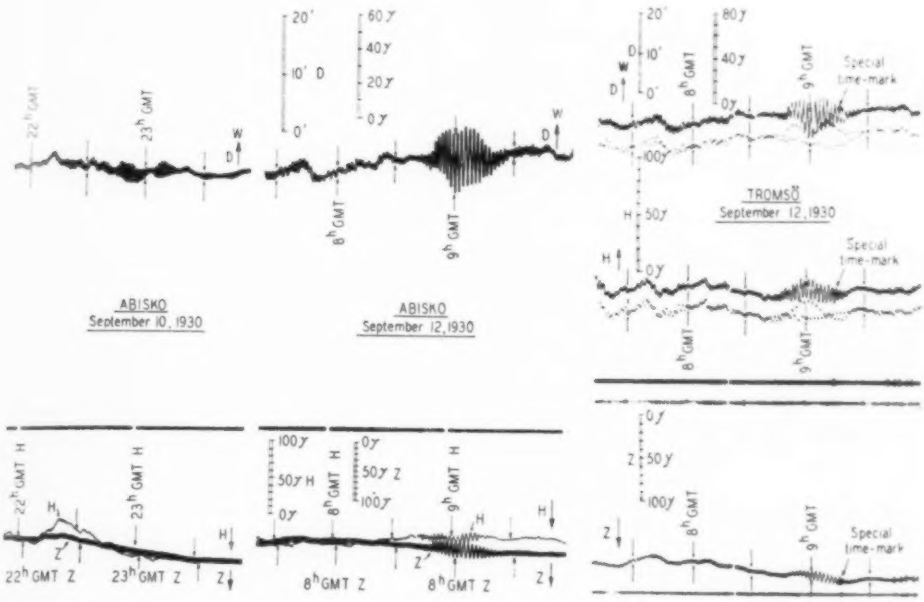


FIG. 28. RECORDS OF MAGNETIC PULSATIONS AT ABISKO AND TROMSÖ, SEPTEMBER 10, 12 AND 30, 1930

more mobile than the exterior layers, not only as a whole but regionally. Even more definite and promising are the results of those magnetic researches which give us also additional information regarding the high atmosphere above the Earth.

We must continue looking to observations and to their discussions perhaps more than to pure theory for further advance in knowledge of the causes and laws governing magnetic time-changes, as well as to provide foundations upon which tests may be made of theory. The rapid developments in physics and in atomic physics during the past decade, particularly in ionization, radioactivity, and high-vacuum electrical research, will permit speculations on the origin and changes of the Earth's magnetic field, which must materially advance fundamental conceptions of the nature and of the constitution of matter.

Some papers bearing on time-changes in the Earth's magnetic field are as follows:

L. A. Bauer, "Principal Facts of the Earth's Magnetism and Methods of Determining the True Meridians and the Magnetic Declination." Washington, D. C., U. S. Coast Geod. Surv., 100 pp. with illus. (1902). [Reprinted with slight changes, 1909, 1914, and 1919.]

D. L. Hazard, "The Earth's Magnetism." Washington, D. C., U. S. Coast Geod. Surv., Ser. No. 313, 52 pp., 1925.

J. A. Fleming, "The Magnetic and Electric Survey of the Earth: Its Physical and Cosmical Bearings and Development." *J. Wash. Acad. Sci.*, 16, 109–132 (1926).

G. Angenheister and J. Bartels, "Das Magnetfeld der Erde." Wien-Harms, *Handbuch der Experimentalphysik*, 25, I, 527–684, 1928.

L. A. Bauer, "Beiträge zur Kenntnis des Wesens der Säkular-Variation des Erdmagnetismus." (Dissertation, Univ. Berlin.) Berlin, Mayer und Müller, 54 pp., 1895.

H. W. Fisk, "Isopors and Isoporic Movements." Union Géod. Géophys. Internat., Sect. Mag. Electr. Terr., *Bull.* No. 8, 280–292, 1931.

A. Schuster, "The Diurnal Variation of Terrestrial Magnetism." Phil. Trans. R. Soc., A, 180, 467–518, 1889; 208, 163–204, 1908.

W. van Bemmelen, "Die Lunare Variation des Erdmagnetismus." Met. Zs., 29, 218–230, 1912.

S. Chapman, "The Lunar Diurnal Magnetic Variation at Greenwich and other Observatories." Phil. Trans. R. Soc., A, 225, 49–91, 1925.

S. Chapman and A. T. Price, "The Electrical and Magnetic State of the Interior of the Earth, as Inferred from Terrestrial Magnetic Variations." Phil. Trans. R. Soc., A, 229, 427–460, 1930.

Terrestrial Magnetism and Atmospheric Electricity. An international quarterly journal. Published by the Johns Hopkins Press, Baltimore, Md. Volume 37 now in progress. Contains articles dealing with all branches of terrestrial magnetism and atmospheric electricity.

FIG. 29. LABORATORY OF THE DEPARTMENT OF TERRESTRIAL MAGNETISM, CARNEGIE INSTITUTION

THE CLINICAL APPLICATION OF BLOW-FLY LARVAE

By Dr. EDWARD F. ROBERTS

ASSISTANT DIRECTOR, LEDERLE LABORATORIES, INC., PEARL RIVER, NEW YORK

Introduction

One of the most fascinating developments in modern medical history has been the recent clinical application on a scientific basis of the larvae of the blow-fly. Contributing largely to this fascination, of course, is the conception of this insect playing a beneficial rather than a harmful rôle with respect to human disease. Whereas efforts were formerly directed wholly towards fly control and fly destruction, increasing interest is centering on methods of optimum year-round breeding and, what is practically a new field, methods of producing larvae free from bacterial contamination. In fact, this latter movement has gained such an impetus that the Bureau of Entomology, U. S. Department of Agriculture, is conducting an extended investigation of the blow-fly in its new relation to medicine.

Historical

Although due recognition must be given to Dr. William Stevenson Baer for having the courage to treat patients with maggots in civilian practice and for carrying out the pioneer work necessary to make the treatment available to the medical profession, the observation that maggots are helpful in curing disease had been made previously, as evidenced by notes in the literature. In retrospect it is interesting to review these briefly.

After the battle of St. Quentin (1557), Ambroise Paré

> found the wounds excessively fetid and full of worms with gangrene and corruption; . . . For more than half a league around the earth was covered with dead bodies, . . . we were the cause of a rising up from the bodies of a great number of large flies gendered by the moisture of the bodies and the heat of the sun; they had green and blue bellies and when they were in the air they cast a shadow on the sun. It was wonderful to hear them buzzing, and wherever they settled they made the air pestilent and there they caused the pest.

D. J. Larrey, the famous military surgeon of Napoleon's armies, notes with respect to the French campaign in Syria (1799) in his "Memoirs of Military Surgery":

> During the progress of suppuration, the patients were only troubled by worms or larvae of the blue flies common in Syria. The hatching of the eggs, which these flies constantly deposit in the wounds or dressings, was assisted by the heat of the weather and by the quality of the dressings, which were of cotton, which alone could be procured in this country. The presence of these insects in the wounds appeared to accelerate their suppuration; but they caused a disagreeable pruritus, and obliged us to dress them three or four times a day. They are produced in a few hours, and increase with such rapidity that in the course of a night they grow to the size of the barrel of a small quill. It is necessary, at each dressing, to use lotions of a strong decoction of rue with a small portion of sage, which destroys them; but they were soon reproduced for want of proper means to prevent the approach of the flies and to destroy their eggs. Although these insects were troublesome, they expedited the healing of the wounds by shortening the work of nature, and causing the sloughs to fall off.

In his "Curiosities of Medical Experience," J. C. Millingen writes:

> During the retreat of our troops after the battle of Talavera (1809), I found the wounds of many of our men, that had not been dressed for three or four days, pullulating with maggots. This was not the case with the Spanish soldiers, who, to prevent this annoyance, had poured olive oil upon their dressings. I invariably resorted to the same practice when I subsequently had to remove the wounded in hot weather.

Perhaps the first intentional use of maggots may be ascribed to J. F. Zacharias, a surgeon in the Confederate Army, who writes of his Civil War experiences:

During my service in the hospital at Danville, Virginia, I first used maggots to remove the decayed tissue in hospital gangrene and with eminent satisfaction. In a single day they would clean a wound much better than any agents we had at our command. I used them afterwards at various places. I am sure I saved many lives by their use, escaped septicemia, and had rapid recoveries.

About 30 years ago there was a famous surgeon in South Chicago whose name was Larkin. Whenever dressings became filled with maggots in the summer time, it was his practice to remove the dressing, clean off the wound with alcohol, brush the maggots into the wound, and re-apply the dressing. His results were good and the treatment was used not only in osteomyelitis but in chronic septic cases as well.

Thus I might go on citing many other experiences, but Dr. Baer's original observation overshadows all the others in its intensity. Lest any of the graphic details might be omitted, I shall relate it in his own words:

Baer's Original Observation

During the late World War an observation which I made among the wounded soldiers led me to believe that the prevention of an infection and the curing of an infection could be brought about by means other than chemical. At a certain battle during 1917, two soldiers with compound fractures of the femur and large flesh wounds of the abdomen and scrotum were brought into the hospital. These men had been wounded during an engagement and in such a part of the country, hidden by brush, that when the wounded of the battle were picked up, they were overlooked. For seven days they lay on the battlefield without water, without food, and exposed to the weather and all the insects which were about that region. On their arrival at the hospital I found that they had no fever, and that there was no evidence of septicemia or blood poisoning. Indeed, their condition was remarkably good, and if it had not been for their starvation and thirst, we would have said they were in excellent condition. When I noticed the extent of the wounds, of the thigh particularly, I could not but marvel at the good constitutional condition of the patients. At that time, the mortality of compound fractures of the femur was about 75 to 80 per cent. even when the wounded had the best of medical and surgical care that the Army and Navy could provide. . . . This unusual fact quickly attracted my attention. I could not understand how a man who had lain on the ground for 7 days with a compound fracture of the femur, without food and water should be free of fever and of evidences of sepsis. On removing the clothing from the wounded part, much was my surprise to see the wound filled with thousands and thousands of maggots, apparently those of the blowfly. These maggots simply swarmed and filled the entire wounded area. The sight was very disgusting and measures were taken hurriedly to wash out these abominable looking creatures. Then the wounds were irrigated with normal salt solution and the most remarkable picture was presented in the character of the wound which was exposed. Instead of having a wound filled with pus, as one would have expected, due to the degeneration of devitalized tissue and to the presence of the numerous types of bacteria, these wounds were filled with the most beautiful pink granulation tissue that one could imagine. There was practically no bare bone to be seen and the internal structure of the wounded bone, as well as the surrounding parts, was entirely covered with the pink, rosy granulation tissue which filled the wound. Bacterial cultures were made, and, while one found a few staphylococci and streptococci still remaining, they were very few in number and not sufficient at that time to cause pus formation. These patients went on to healing, notwithstanding the fact that we removed their friends which had been doing such noble work.

Pioneer Investigation

The experience just cited made an indelible impression on Dr. Baer's mind. In September, 1928, four children came to the Children's Hospital School, Baltimore, each one of whom had been operated on three or four times for chronic osteomyelitis and treated over a period of from one to five years. Being baffled by the means usually employed in treating such cases, Dr. Baer thought it time to put to practical use the observation he had made on the battlefield. First, a thorough operation was performed with removal of all dead tissue that was accessible. No antiseptics or chemicals of any

kind were used, since it was desired to give the maggots full credit for any improvement that might be noted. Larvae of the blow-fly were obtained from the immediate neighborhood and without any attempt at sterilization they were placed in the wounds. At the end of about six weeks, the wounds had entirely healed, not only in the deeper structures but even as to the skin.

In some of the early cases, however, certain secondary infections, particularly those caused by anaerobes, were encountered. In three cases gas bacilli were found in the wound. This was disconcerting, but the patients showed no clinical evidence of gas gangrene. However, experiments were discontinued until the problem could be solved. Six guinea-pigs were inoculated with gas bacilli and then treated at various intervals with maggots. All these guinea-pigs made a rapid recovery with complete function in the infected parts. Therefore, gas gangrene infection was not feared and treatment was resumed until suddenly tetanus (lockjaw) bacilli were discovered in eight cases. All wounds were immediately washed out and the patients given tetanus antitoxin. Four cases showed no clinical symptoms, but two progressed to severe lockjaw. One of these who had advanced tuberculosis died, notwithstanding the administration of large doses of antitoxin. The other case finally made a complete recovery after a long bitter struggle against the infection. It was then realized that in civil practice it would be necessary to have sterile maggots, and that to insure a constant supply, both winter and summer, flies would have to be bred in the laboratory.

At first attempts were made to sterilize the maggot itself, but this proved difficult and the conclusion was reached that organisms were carried in the intestinal tract where they were inaccessible to the sterilizing solution. A technique was then devised whereby the fly eggs were disinfected in a bichloride of mercury solution and the hatched maggots were proved by bacterial cultures to be free from organisms. Using larvae disinfected in this manner, Dr. Baer proceeded with the treatment of chronic osteomyelitis until his death in April, 1931, when he had accumulated well over 200 cases with 95 per cent. cures in children and 85 per cent. cures in adults. His pioneer work was so well carried out and the fame of his clinic spread so far that even his death did not diminish the increasing interest in maggot therapy. To-day the treatment is being applied throughout the United States, with several hospitals raising their own maggots, and the success attained in this country has prompted inquiries from surgeons in such far distant localities as Sweden and the Philippine Islands.

Breeding of Flies

A constant supply of fertilized eggs for disinfection is insured only by careful attention to methods of fly breeding. We have found environmental factors, particularly temperature and humidity, to be fairly important and therefore our incubators are regulated for a temperature of 80° and a humidity of 50 per cent. At first ventilation was thought to be essential, but experience has not shown this to be the case. Artificial illumination is provided by spacing electric light bulbs between the side windows of the incubators. At one time in our early work we resorted to ultra-violet light as a stimulus for egg-laying, but under normal conditions ultra-violet irradiation is not necessary.

The most satisfactory type of fly cage is one of light wooden framework with a durable mosquito net covering. A small door allows the passage of a Petri dish containing food in and out of the cage and at the side of the door a hole is bored just large enough to accommodate a glass vial. Daily rations for the flies consist at present of a sugar-water mix-

ture in which the white of an egg is whipped. The tendency for the flies to drown in the fluid is obviated by placing a piece of porous sponge rubber in the dish. We have tried out various types of foods, including yeast, strained honey, orange juice and ripe banana, but the recipe now in use seems to answer best the requirements for readily available carbohydrate and protein. For the purpose of egg-laying, the flies are provided with a strip of meat folded several times on a toothpick and placed in the glass vial. The folding of the strip is intended to humor the flies, since they endeavor to hide their eggs among the wrinkles of the meat. Raw beef is used by most laboratories, but we have found hog spleen to be more nutritious and more conducive to good egg-laying.

Our studies have been concerned wholly with two species of the blow-fly—Phormia and Lucilia, which I transported from Baltimore a year ago as eggs and pupae. In our laboratory the stages in the life cycle have proved to be quite variable. The eggs hatch in 8 to 24 hours, average 16 hours; the larvae reach maturity in 5 to 9 days, average 7 days; they remain in the inactive prepupal state for a few days before gradually transforming into pupae. The average duration of the pupal stage is six days. Oviposition takes place within five to seven days after the flies emerge and continues for about three weeks. The entire metamorphosis of the blowfly, therefore, requires from twenty to thirty days.

For breeding stock, fly eggs are transferred with the meat on which they are laid to a glass jar in a dark compartment. We have endeavored to breed larvae on various kinds of sterilized media, such as a chopped beef-calf brain medium, but anything other than native protein seems to yield flies with impaired vitality. When the larvae have become full-grown and have ceased feeding, the jars are placed in deep enamel containers, surrounded with sawdust, the cheesecloth covering of the jar removed, and the larvae allowed to migrate into the sawdust of their own accord. The inside of the enamel container is rimmed near the top with vaseline to restrain those individuals seized with the wanderlust. The sawdust is examined two or three times each week for the presence of pupae which are transferred to sterilized fly cages for hatching.

Disinfection of Maggots

Of course, the vast majority of the fly eggs are disinfected to procure sterile maggots for the surgeon's use. The description of the technique followed is taken from an article by Child and Roberts, which was published in the *New York State Journal of Medicine* for August 1, 1931.

> The main problem involved in preparing maggots suitable for clinical application is the use of a disinfecting procedure that is bactericidal without being insecticidal. . . . Accordingly, attention was turned toward the development of a procedure which would result in a minimum of bacterial contaminations and as nearly as possible a 100 per cent. hatch of the disinfected eggs. After extensive experimentation, the following technic was devised:
>
> Fly eggs laid by the species enumerated above on either hog spleen or raw beef are removed by gently brushing off the clumps with the flat end of a tooth pick into a beaker of sterile distilled H_2O. The water should be at a temperature of 4° C. to prevent hatching of the eggs before disinfection takes place.
>
> The apparatus for disinfection consists of a covered Gooch crucible attached to a filter tube by means of a thin-walled rubber tubing collar. The crucible and cover are sterilized separately, the crucible containing a small piece of fine mesh cheesecloth placed over the perforations. A short piece of ordinary rubber tubing is connected with the lower end of the filter tube which, with collar tubing attached, is immersed in 3 per cent. phenol when not in use. When the crucible, cover, and filter tube have been assembled, a pinch clamp is attached to the small-sized rubber tubing and the apparatus is ready for disinfection.
>
> Approximately 1100–1200 eggs are transferred to the cheesecloth layer in the crucible and are rinsed several times with sterile distilled H_2O (temperature 4° C.) to mechanically

remove bacteria. The pinch clamp is tightened and the egg clumps are thoroughly disintegrated by gently agitating them in 3–4 cc of a sodium hypochlorite solution yielding 0.5 per cent. available chlorine. Complete separation of the clumps is effected in ½–1 minute, and is important in that it makes the whole surface of each egg available to the action of the disinfecting agent.[1] After loosening the clamp, the eggs are thoroughly rinsed with sterile distilled H_2O to remove all traces of chlorine, the clamp is re-tightened, and a neutral solution containing 4 per cent. formaldehyde added to fill up the crucible. The eggs are exposed to this disinfectant for 3 minutes, then the clamp is loosened, and the eggs are rinsed a third time with sterile distilled H_2O. All agents in the above procedure are used at a temperature of 4° C.

As soon as most of the fluid has drained off, the piece of cheesecloth holding the disinfected eggs is transferred with sterile forceps to a 2 oz. bottle containing about 4 cc of a sterile semi-solid medium. The medium consists of 1 per cent. agar and desiccated liver. Experience has shown that poor hatching results if the cloth with eggs is dropped on the medium and therefore the bottom surface of the moist cloth is smoothed out so that it will adhere to the bottle wall.

The bottle is then placed in a hatching incubator (regulated for temperature, humidity, and ventilation with exclusion of light). Twenty-four hours later hatching is completed and the tiny maggots are tested for sterility by inoculating duplicate sets of fermentation broth tubes for detecting aerobes and deep meat tubes for detecting anaerobes.

After sterility-testing the bottle of maggots is returned to the incubator for another day of growth and then the bottle is transferred to the chill room (temperature 4° C.) to await the results of the sterility tests. Each bottle is held whenever possible for a 4-day reading on the sterility tests before it is shipped. On the average, the technic as described above results in 90 per cent. hatches free from bacterial contamination.[2] It must be remembered that each bottle is subjected to a 4-tube test and if only one of these tubes shows a contamination within 4 days after testing, it is not released. Moreover, all tests are actually held in the incubator 7 days as a check on the dependability of the sterilizing process. The hatch after disinfection varies between 90 and 100 per cent. of the hatch observed from non-disinfected eggs, the fertility of the eggs being comparable.

The method of shipment consists in packing the bottle of maggots next to a can of natural ice which is then surrounded by a 4–5 inch layer of pulverized cork as insulation between the chilled maggots and the walls of the carton. Since the ice in the package and the type of medium in the bottle both serve to retard the growth of the maggots while retaining their viability, they remain during transit at approximately the same 2-day stage of growth at which they are shipped, and therefore may be left in the wound 5 days unless unfavorably affected by the wound secretions or lack of food. Upon arrival, a bottle of maggots may be kept in an icebox at 4° C. for a few days before implantation if necessary, but this is obviously not desirable since the maggots are perishable and can not be stocked indefinitely. Such a procedure is certainly not feasible when a bottle remains more than two days in transportation.

Attributes of Maggot Therapy

The question naturally arises in your minds, "What are the specific benefits of maggot therapy?" As expressed by Dr. Jacob Myers at the Illinois State Medical Society meeting, May 6, 1931, "the maggot treatment is advocated as an economical, efficient form of therapy which produces healing without draining sinuses in the shortest length of time, with the quickest return of function and the least retraction of the scar of any treatment in use at present." Maggot therapy succeeds in accomplishing what surgery has failed to do—namely, to eliminate bacteria and remove necrotic tissue. Bacteria probably are destroyed in several ways. One of the first effects to be noticed in the wound is a change from an acid to an alkaline reaction, presumably due to the vigorous production of ammonia which accompanies the liquefaction of meat by larvae. Dr. Baer believed that the alkalinity was partly responsible for the killing of microorganisms. Undoubtedly the maggots destroy bacteria mechanically by ingesting and digesting them. Possibly also a soluble substance is excreted which has a definite germicidal action. Certain it is that bacterial counts taken weekly show a marked progressive diminution in the number present. The end result

[1] The chlorine dissolves the albuminous coating that holds the eggs together in clumps.

[2] Average now 95 per cent.

of this germicidal action is that the maggots themselves can live in contact with the wound only a few hours after several implantations.

The removal of dead tissue by the maggots is almost phenomenal. This is assisted by the necessity of the blow-fly larva to liquefy its food, accomplished by the liberation of proteolytic enzymes. Thus the wound secretions are greatly increased, providing adequate drainage. Unlike the surgeon's knife or the chemical antiseptic, the maggots discriminate between the living and the dead tissue. Thus they seek out hidden pockets of infection which might otherwise perpetuate the disease. They separate dead particles of bone and feed on devitalized tissue until they arrive at the bleeding area. The efficient removal of all necrotic tissue allows the natural processes of repair to operate unhindered. Reddish compact granulation tissue grows over and attaches itself to the healthy bone and the wound fills up from the bottom, leaving the epithelium to merely grow over the surface. Thus the contour of the wound resembles the original shape of the part and disfiguration from deep pitting scars is relatively infrequent.

There is no purulent odor to the treatment and free pus is never apparent. A few patients have described a slight biting sensation possibly due to the proximity of the maggots to a sensory nerve. Another disadvantage reported has been an occasional rise of temperature on the third or fourth day following an implantation. This thermal response has been correlated with profuse discharges from the wound and is thought to be caused by insufficient drainage.

Indications for Maggot Therapy

I have purposely chosen the title "Clinical Application of Blow-fly Larvae" instead of the "Larval Treatment of Chronic Osteomyelitis," because I believe that maggot therapy is applicable to many other suppurating and sloughing types of wounds. It can not be denied that the case is proven only for osteomyelitis, but evidence is rapidly accumulating to show its effectiveness in other diseased conditions. Based on a series of seven tuberculous cases, Dr. Baer concluded as follows, "In open tuberculous abscesses, with or without secondary infection, wide exposure followed by maggot treatment has proved surprisingly effective." Not only are tuberculous lesions receiving attention but also chronic leg ulcers and even carbuncles are being treated in several clinics with most gratifying results.

With the growing realization that a powerful ally is now available to the host in its struggle against the parasite (bacterium), I firmly believe that maggot therapy will find a wider and wider field of usefulness.

A SIMPLIFIED CALENDAR

By Dr. EDMUND BURKE DELABARRE
PROFESSOR OF PSYCHOLOGY, BROWN UNIVERSITY

THE inadequacies of our present calendar need no comment. Decisive steps are being taken toward its revision, by the League of Nations and by influential organizations in many countries. The change to a new calendar, more simple and useful, is inevitable. When it comes, it is of the utmost importance that the new device should be as perfect as it can be made. Absolute simplicity is unattainable, because day and year, week and year, lunar month and year, are incommensurable periods of time. By simple adjustments and conventions, however, the difficulty can be overcome and a close approximation to perfection and simplicity attained.

Of the two alternative plans now most in favor, each has avoidable imperfections. One, the thirteen-month plan, has the very great advantage of fixed association between week-day and month-date, since every month begins on Sunday and has 28 days. But it does not adapt itself easily to an even division of the year into quarters, which is desirable for two reasons: the astronomical fact that the seasons do so arrange themselves; and the common commercial practise of conducting various businesses with reference to quarterly periods. The other, known variously as the Swiss Calendar, the World Calendar, or the New Era Calendar, has the advantage of an even division of the year into quarters, two months in each quarter having 30 days and the other 31. But it involves the disadvantageous retention of a disparity between week-day and month-date, although to a much less confusing degree than the present calendar. Both systems propose to fill out the year by insertion of an intercalary "year-day" each year, belonging to no month, and of a similar intercalary "leap-day" in leap years. The New Era proposal[1] seeks to meet certain religious objections by calling the "year-days" in successive years by successive week-day names, and the "leap-days" in successive four-year periods by their own successive week-day names, thus adding a "year-week" to the other weeks once in seven years, and a further "leap-week" once in twenty-eight years. This would involve the peculiar situation of having "weeks" whose successive days are a year or four years apart, and of inserting between Sunday, December 31, and Monday, January 1, every year, a week-day called Tuesday, or Friday, or any other week-day name in its turn.

Probably one reason why calendar reform has not met with more rapid and enthusiastically-greeted progress has been the conflict of the two systems proposed, and the fact that each falls short of a completely acceptable system. A device possessing the advantages of both and the imperfections of neither ought to have a much better chance of early adoption. Such a device is entirely feasible, and involves changes that are hardly more numerous and radical than those necessitated by either of the others. Its individual features, of course, with perhaps one or two exceptions, have been thought of by others already. As a whole, it more nearly resembles a scheme suggested in 1910 by T. C. Chamberlin,[2] than any other; but in some important ways I regard it as better. As a total assembly, so far as I am aware, it is new, and it seems to me appropriate that it should be baptized with the name of the city in which the idea of it was born, and be known, therefore, as the Providence Simplified Calendar. Should it meet with sufficient support to secure

1 Howard C. Warren, *Science*, n. s., 47: 375–377, 1918; and THE SCIENTIFIC MONTHLY, 33, 440–442, 1931.

2 *Science*, n. s., 32, page 757, 1910.

eventual adoption, just as dates under the Julian calendar are called Old Style (O. S.), and those under the Gregorian calendar are called New Style (N. S.), so under this one they could be called Simplified (or Scientific) Style (S. S.).

The largest attainable perfection, it would seem, ought to include the following features: (1) The calendar for all years to be the same, except for the regular introduction of a leap-day at intervals as at present. (2) Beginning of year to be replaced where it astronomically belongs, at the winter solstice. (3) Year divisible into even quarters, both for astronomical and for business reasons. (4) Retention of twelve months, each of exactly four weeks and of exactly 28 days. (5) Inclusion of an exactly even number of weeks in the year.

At first sight, this combination seems to be impossible. It is feasible, nevertheless, if we introduce three conventions against which no strong reasons can be alleged, in addition to the already accepted convention of leap-day. First, let each quarter begin with an intercalary or seasonal week, belonging to no month. Second, let New Year Day, and Leap Day when it occurs, also belong to no month, but be regarded as zero-day of the week which follows. Third, let each of these intercalary days be called Sunday, to be followed by Sunday the first of the week. Thus there would occur, once each year and twice in leap years, a Double Sunday. This Sunday would be astronomically two 24-hour days. But, for religious and legal purposes, it could be taken symbolically as one 48-hour day. Such a convention would emphasize the importance of the Sabbath rather than interrupt its regular recurrence, and would give the year, in the only way possible, an exactly even number of weeks. We are accustomed already to the convention of a 23-hour day and a 25-hour day each year, involved in the adoption of the daylight saving plan. It would be quite as easy to adapt ourselves to a 48-hour day once or twice a year.

Most of the other "simplified calendars" that have been proposed retain January 1 as New Year Day, and hence insert the extra Year-Day as the last one of the old year. There are no very good reasons for doing this, when so much more of meaning will attach to the day if treated in the manner that I suggest. Historically, the beginning of the year has moved around throughout the entire calendar. It is only accident which has placed it in its exact present position. But there is a significance, inexactly applied, that has determined its place. It represents the occurrence of the winter solstice, and has become shifted from the day when that event occurs. At the true solstice, the sun has reached its farthest position south of the equator and begins to return, with promise of new warmth and new growth, to northern latitudes. From far prehistoric times men have made this event an occasion for celebration and rejoicing.

We ought to restore this immemorial meaning of "New Year," which men in northern climes will never outgrow, by placing it at what we know to be its exact and proper date, as nearly as it can be done. Because of the circumstances which necessitate leap-years, the actual solstice falls sometimes on December twenty-first, sometimes on the twenty-second. Of these two days between which we have to choose, the earlier of them, December twenty-first, seems the more appropriate. It has the added great advantage of leaving two full business days between the Double Sunday and Christmas day, whereas the choice of the twenty-second would leave but one. This change will involve, it is true, dropping eleven days out of the year when the new system goes into effect. But this is a simple device which has been applied before without any disastrous effect: in 1582 in Catholic countries, in 1752 in England and America.[3] The best time to do it would

[3] Gregory XIII, "perceiving that the measure was likely to confer a great *éclat* on his pontificate, undertook the long desired reformation" (Encyc. Brit., ed. 11). The change went

be when December 21 falls upon a Saturday. This will occur in 1935, next in 1940, and again in 1946. In the first year of its adoption the day would be called Saturday, New Year Day, 1936, or 1941, or 1947. Thereafter, it would always be Sunday, New Year Day of a new year, to be followed by Sunday, Winterweek 1, and a week later by Sunday, January 1, which would no longer have any "new year" significance. Christmas, another symbol of birth and of beginning of new and better things, would come appropriately after New Year Day, falling always conveniently on Wednesday, the fourth day of New Year Week, or Christmas Week, or Winterweek, or whatever it may be called. This would leave it in exactly the same position in the astronomical year which it now occupies—four days after the solstice.

The year begins, then, at the winter solstice, with New Year Day, always a zero-Sunday. After it follows Winterweek, beginning with Sunday the first and ending with Saturday the seventh. Then follow three months, January, February and March, each beginning with Sunday the first and ending with Saturday the twenty-eighth. There is always exact fixity between date and week-day. Next comes Springweek, or Easter Week, or whatever it may be named. Its first day, Sunday, will correspond as nearly as possible to the time of the vernal equinox. It will be followed by three months of 28 days each, named as at present. Next, when necessary, comes Sunday, Leap Day, followed by Sunday, Summerweek 1, at summer solstice as nearly as possible. Three months of 28 days each complete the third quarter of the year. The fourth quarter begins, at autumnal equinox, with Sunday, Autumnweek 1, and this week is followed by the last three months of the year, again with 28 days each. Counting Double Sunday as legally and symbolically one day, each quarter contains exactly 91 days. The year ends on the present December 20, which becomes the new Saturday, December 28. By means of the convention of Double Sunday, it contains exactly 52 weeks; and by means of the four inserted seasonal weeks, it is divisible into four exactly even quarters. It has the inestimable advantage of having one calendar serve for every year, and of having month-date or week-date correspond to the same week-day name in every month of every year.

The only disadvantage of this proposal is that it interferes slightly with the familiar conception of the month. But the month, founded on lunar periods which can not be reconciled conveniently with solar periods, must suffer some change in any revised calendar. Either we must insert a new one, or we must have them unequal in length and incommensurable with the week, or we must adopt the device of four inserted separate weeks. For purposes of industrial, financial, commercial and many other established practises, the equal quarters of the year are more important than the particular arrangement of months. Wages, salaries, dividends, interest and other transactions are based much more often on unit-periods of hour, day, week, quarter, half-year and year, than they are upon months. Any practise now adjusted to months will have to be revised to fit any new calendar, and can be adjusted to this one as readily as it could to any other. In fact, it would be easier to make calculations dealing with these new months and quarter-months than to continue to make use of our present variable calendars. Monthly bills and wage schedules, for instance, perhaps may be adjusted to cover five weeks in the first third of each quarter, and four weeks in the others. There would be no difficulty attending the adoption of any other manner of dividing the quarter into thirds or other approximate monthly periods that might

into effect in 1582 in Rome, parts of Italy, Spain, Portugal, France; in 1583 in Catholic states of Germany; in 1700 in Protestant states of Germany; in 1752 in England, where September 3 became September 14, and new year was changed from March 25 to January 1.

suit individual convenience, and a year or two of use would lead without inconvenience to substitutions that would smooth away all difficulties.

The names which I have proposed tentatively for the inserted weeks are Winterweek, Springweek, Summerweek, Autumnweek. They are words of about the same length as the names of most of our months, and each is abbreviated readily by use of its first three letters. They do not apply, of course, so appropriately to seasons south of the equator. Perhaps better names may be devised; or perhaps these are best, with the consequence that southern peoples must accept conventions which have their origin in northern temperate zones.

The new month-dates will differ from the old ones by an average of only five days, with extreme difference of two days at the least and eight days at the most. The new Sunday, January 1, will be the old December 29, the old January 1 becomes the new Wednesday, January 4. One great advantage of this, as of the other proposed new calendars, will be the fixed connection between holidays and anniversaries, and the days of the week. The fixation of the day of Easter is almost sure to be decided upon by religious bodies before long. Some other American anniversaries would be as follows, if they are to occur on new dates corresponding to their old ones: February 12 (Lincoln): Wednesday, February 18; February 22 (Washington): Saturday, February 28; March 4 (Inauguration): Tuesday, March 10; May 30 (Decoration): Friday, June 6; July 4 (Independence): Friday, July 6; first Monday September (Labor): Monday, September 9; October 12 (Columbus): Sunday, October 15; first Tuesday November (Election): Tuesday, November 10; November 11 (Armistice): Tuesday, November 17; last Thursday November (Thanksgiving): Thursday, December 5; December 25 (Christmas): Wednesday, Winterweek 4. The academic year for educational institutions will be greatly simplified and stabilized. Brown University, for instance, if it should conform to the nearest present average dates, would begin its academic year always on Wednesday, Autumnweek 4, and hold Commencement on Monday, June 23. It would be easy, however, to make readjustments, if a more efficient distribution of holiday periods should make them desirable.

Conservative clinging to established customs is one difficulty in the way of the introduction of any kind of change. This must yield when confronted with the promise of large increase in efficiency and satisfaction that is sure to follow the change. Religious prejudice, probably, is the only other serious difficulty to be met. A new universal calendar must come as near as it can to satisfying the demands of all religious bodies, non-Christian as well as Christian. Any of them which maintain calendars different from ours, as some of them do, can adjust themselves to the revised calendar as easily as they could to the one in present use. Any religious belief that the week of seven days, or the lunar month, is divinely ordained, is confronted with the indubitable fact that the year is just as surely a divinely appointed period, and that it is incommensurable with day, week or month. If the Divine Being is responsible for any of these things, it is evident that he has instituted conflicting divine schemes of time division, and has left it to the ingenuity of man to reconcile them as wisely as he can according to his own needs. He must make adjustments of some kind, and always has. It would seem that the adjustments suggested in this paper are the simplest and most logical that could be devised, combining the advantages of the other proposed schemes with the disadvantages of neither of them. The important thing, however, is to get one of the three adopted, whichever one of them can secure practically unanimous endorsement.

ENVIRONMENT AND HEREDITY

By Dr. A. S. PEARSE

PROFESSOR OF ZOOLOGY, DUKE UNIVERSITY

ENVIRONMENT is what surrounds anything. On the earth it is made up of psysical things, such as wind, waves, water, rocks, and oxygen, and of organisms, such as food plants and animals, lurking enemies, and astute competitors. For man and for some other animals there is a social enviroment, which consists of such things as the boys at the office, grammar, golf, bow ties, bridge games, and ladies' aid societies. Man has reared culture as the fairest flower in his time-binding garden of civilization. Man not only struggles and lives in his environment, but he aspires to live in the best possible way—to be a cultured gentleman.

Environment continually changes. Daily and annually there are minor or extreme fluctuations in humidity, wind, temperature, the stock market, total sales, and religious converts. At times there are major changes in environment. Glacial epochs cool the earth and change the volumes of oceans; great upheavals or depressions of the earth's crust make mountain ranges or new oceans; empires change to republics. During glacial times there were reindeer in Italy. The pantaloons and stocks that grandfather wore during civil war days are now ridiculous and archaic. The outstanding quality of environment is change—fluctuation, mutation, modification, and transformation.

In environment lives the organism—plant or animal. This organism has certain well known qualities, but when one tries to define it in critical scientific terms, many difficulties are encountered. An organism has metabolism; the power of growth, repair, and reproduction; specificity; manifoldness, and peculiar organization. Yet it is made of matter and its usual activities are associated with well known chemical and physical processes. Perhaps it is nothing but matter and energy; perhaps it has in addition to these some vital spark which keeps it organized and harmoniously living. All that science has been able to say about the organism is that it is a "coordinated, self-perpetuating, system of activities." Its primary quality is continual activity. Like environment it is always changing.

An organism never exists for an instant without its environment. Furthermore, every organism is adapted to its environment—it fits. A fish belongs in water; a bird, in air; a snake, on its belly on the surface of the earth; a Negro in the tropics; an Eskimo in arctic regions. An ever-changing organism thus lives in an always-varying environment and must continually be adapted to it. This is a complex and trying situation which may well discourage any organism which is earnestly struggling to survive. It is mitigated somewhat by the fact that every organism has certain powers of adjustment, so that it can change from day to day or from year to year to keep pace with minor changes in environment. A man grows callouses on his hands if he spades; a tick can live for four years without food. Some animals and plants have remarkable powers of adjustment or of toleration for variations in environment. Such types usually have wide geographic ranges and often live in a variety of habitats. Organisms with narrow ranges of adjustment are correspondingly limited. A house fly lives in many parts of the earth and subsists on many foods; the honey bee depends on certain types of flowers and can not thrive without them.

Heredity is jealous of change. Its mechanisms, as they are at present

known to science, permit animals to mix their qualities in a nearly endless variety of combinations, but they seldom or never permit species to change. The transfer of hereditary qualities from parent to offspring through particular chromosomes and genes is well known. Recently there have been several very illuminating discoveries in this particular field. But what causes animals to vary, to change their limits of toleration and adjustment, is still a mystery. Scientific experiments which have been intended to transform one species into another on the whole have been quite negative. A species can be selected so that potential characters which it already has may be emphasized, but experiments which have extended over a limited range of time have not resulted in new species. Osborn[1] says, "This incredibly slow rate exposes the futility of modern experimental research which would produce a new character in a single year or in a few seconds."

Evolution is thus left by science between two horns of a dilemma. Animals certainly have changed and have been transformed into new species. But when Nature's favorite child tries to produce species for himself, Heredity blocks his progress into the promised Land of Discovery, and ever turns him back into the fields of Adjustment, Hybridization, Mendelism, and other long-tilled areas. But, if species have evolved out of preexisting species in the past, they are probably doing it to-day. Perhaps if man can carry his cumulative scientific knowledge, his experiments and his discoveries on for another million or billion of years, he may discover the secret of evolution. Perhaps some fortunate genius may discover such secrets during the span of his life. Until the time comes when there is scientific evidence on which to base general laws there will be controversy. The advocates of either heredity or environment as the primary factor in evolution will go on speculating and asserting. Every mother believes that Environment is a magician who can make the son of a drunken ne'er-do-well into a competent, great, and noble personality. Every father knows in his secret heart that he is more or less of a failure, but lives in the hope that his boy may become a superman if he gives him golden opportunity. This is sentiment, and perhaps also a grain of vanity, for the parent excuses himself to himself by laying the burden of failure on lack of opportunity. Science is judicial and, though generally kindly in spirit and open minded, she hates Sentiment. Her favorite children are Truth and Evidence. She tolerates Theories only as strictly temporary incumbents of positions that later are to be filled by established Natural Laws.

It must be admitted that at present scientific evidence gives little support to environment as a primary cause for the production of new species. In the pamphlet[2] which gives brief discussions of the exhibits which were recently shown in connection with annual meeting of the Carnegie Institution, there is evidence on this point. Dr. H. M. Hall has been working many years on a genus of plants to discover whether what have been called species are the products of adjustment to present environmental conditions or whether they are due to heredity. He says, "The investigations exhibited are not designed to give a conclusive answer to this very debatable question, but thus far no changes have been induced by environmental conditions which have the appearance of becoming hereditary." Dr. H. E. Crampton, who has made extensive studies of land snails of the genus Partula on the islands of the Pacific Ocean, remarks, "The variations among species of this genus and the variations within any

[1] H. F. Osborn, "New Concept of Evolution Based upon Researches on the Titanotheres and the Proboscidians," *Science*, 74: 557–559, 1931.

[2] E. C. MacDowell, "Exhibition Representing Research Activities." Carnegie Institution, Washington, 1–32, 1931.

single species are to be interpreted in terms of innate or congenital factors, and the circumstances of 'environment' are not in any way causal with reference to the characteristic qualities of a localized race, variety or species." Dr. A. M. Banta reports a case he actually observed where the offspring of one crustacean survived unusually high temperatures. It is noticeable that he gives no suggestion as to how the new limits of toleration were acquired; he is too scientific. He is satisfied merely to state that he did observe the origin of a new range of toleration in a species. Dr. E. C. Case, who has published two great works on the origin of tetrapods in relation to climate, concludes that land vertebrates originated when the environment was quite monotonous for a very long period.

Heredity gives an animal its native ability. Environment gives an animal opportunity. A college education will not transform a fool into a wise man, but it should give a man opportunity to develop what native ability he has. There is little evidence that any animal can change its inherited abilities during its life. If a potentially great man was shut up in a dungeon and fed through a hole in the door, he could never get experience and education enough to develop. He would probably never write poetry, build railroads, or lead armies. He could not develop completely without his environmental opportunities. So it is with all animals.

The writer has been privileged for a number of years to study the migrations of animals from the ocean into freshwater and land habitats. These migrations have taken place during the past and are progressing in many parts of the earth at the present time. Animals have left the stable, dependable ocean in order to take up a precarious, uncertain life on land. Animals which are forced to live in a changeful environment, continually seek to attain some degree of stability. In going from ocean to land animals have escaped certain dangers and competitions, and incidentally they have developed mechanisms which enable them to live in the extremely variable land habitats by attaining more and more internal stability. Land animals have effective, and often elaborate, mechanisms for conserving water, regulating temperature, maintaining internal fluids at optimum concentrations, respiration in air, reproduction, locomotion and sensation in air.

In connection with the study of landward migrations I have often been impressed with the idea that new species perhaps arose when there was a segregation of certain types into particular habitats in order to avoid competition. The four common species of hermit crabs at Dry Tortugas are arranged in definite zones and their gills decrease in number toward the land. Those that live in the ocean have 26 gills; the species which is established on the reefs at high tide mark has 18 gills; and the land hermit crab has 14 gills. On the mud flats at the mouth of the mighty Menam in Siam there are three species of gobies which hunt together on the beaches. These land fishes show little or no arrangement into zones, but a careful study of their habits showed that they were quite definitely segregated, so that they avoided competition. The largest species subsisted largely on crabs and large insects and had a short intestine; the medium-sized species ate little but algae and had a long intestine; the smallest species ate ants and other small animals and had a short intestine. Even the parasites of these three gobies were strikingly different. Though the three species lived together continually, they were not competing. After encountering many such instances I have tentatively come to the conclusion that perhaps a new species begins when a group of animals is able to invade an unoccupied niche in nature, and thus avoids competition. Such a group probably soon attains some degree of stability in relation to certain environmental factors and gradually makes

adjustments which make it more and more closely adapted to existing conditions. What causes such an incipient species to change its habits and its limits of toleration is of course unknown. Evolution may be more or less due to isolation (Wagner), orthogenesis (Eimer), natural selection (Darwin), the transmission of acquired characters (Lamarck), hybridization (Johanssen), aristogenesis (Osborn), accumulated mutations (Morgan), or other things. Osborn[1] recently published a list of the principles of evolution as shown by paleontology. Such "laws" of evolution are not yet firmly established; they are still in the theoretical state. This is the challenge and the inspiration for the young biologists.

It may seem that this attempt to set forth the present status of environment and heredity in relation to evolution involves a rather hopeless philosophy for application to every-day life. There seems to be little doubt that any organism, man included, is born with a certain equipment in the way of capacity or ability. Environment may give the organism the opportunity to bring this to the greatest possible fruition. Every man is born with certain aptitudes for mathematics, music, business, art, politics, mechanics, or what not. Environment as it exists in climate, food, dwelling, home life, school, and state should give him unlimited opportunity to develop what he has. It is the obligation of civilization to make environment such that each individual has opportunity to develop the best personality that his given abilities permit.

To a scientist this outlook is inspiring. Present day biology says, "Be what you are. Waste no time in trying to make yourself what you are not, and do not try to convince the world that you are something different than what you are. Take your given capacities and make the best possible; struggle and improve. Throughout life you must change—adjust as environment changes. Perhaps with your unique intellect you can even change your environment to suit your particular abilities. Environment is opportunity."

I find the great thing in this world is not so much where we stand as in what direction we are moving. To reach the port of heaven we must sail, sometimes with the wind and sometimes against it,—but we must sail, and not drift, nor lie at anchor.—*Oliver Wendell Holmes.*

POPULAR USAGE OF THE TERMS "INSTINCT" AND "INSTINCTIVE"

By Dr. RICHARD STEPHEN UHRBROCK

PSYCHOLOGICAL terminology is being used with increasing frequency by the newspaper writer, the magazine contributor and the novelist. If we are to judge by examples that have appeared in leading publications during the past year, any phenomenon of behavior that tends to exhibit even a minor degree of stability sooner or later will be referred to as "instinctive."

Contemporary writers of all classes make frequent use of the words "instinct" and "instinctive," but, with very few exceptions, they use them so loosely that they have almost spoilt them for scientific purposes. On the one hand, the adjective "instinctive" is commonly applied to every human action that is performed without deliberate reflexion; on the other hand, the actions of animals are popularly attributed to instinct, and in this connexion instinct is vaguely conceived as a mysterious faculty, utterly different in nature from any human faculty, which Providence has given to the brutes because the higher faculty of reason has been denied them. Hundreds of passages might be quoted from contemporary authors, even some of considerable philosophical culture, to illustrate how these two words

are used with a minimum of meaning, generally with the effect of disguising from the writer the obscurity and incoherence of his thought.[1]

The following examples of the popular usage of the terms "instinct" and "instinctive" have been culled from a variety of sources. Some of the writers who have contributed to this list are famous wherever English is read and spoken. The identity of others is concealed, owing to the fact that it is the policy of American newspaper editors not to sign their articles.

(1) The officer knew instinctively that the man was unfamiliar with the gear shifts in that particular make of car.

(2) This ability must be linked with sound business judgment, promotional instinct and a sense for news.

(3) Henry P. Davison, who at forty was a partner in J. P. Morgan & Company, was not born to riches, but he must have been born with a natural instinct for banking.

(4) Instinctively he had dropped his fingers towards his right coat pocket, but he thought better of that maneuver and slightly raised his hands.

(5) Hoppe is probably without a rival in his instinctive knowledge of the angles of a billiard table.

(6) Versed in his youth in the use of the "lazo" and the "boleadoras" than the pen, I think his love of nature set him on to write instinctively, just as a gaucho child, putting its little naked toe upon the horse's knee, climbs up and rides because he is compelled to ride or remain a maimed and crippled animal, traveling the plains on foot.

(7) Yes, almost a commercial instinct.

(8) Suddenly a camera man snapped its shutter in the ex-Premier's face and the commercial instinct of America was satisfied.

(9) Lacking the Saxon training for self-government and the Saxon instinct for individual rights, they have not felt sorely the grievances under which the English speaking colonies smarted.

(10) Was the West African instinct getting the upper hand in him over the Christian gentleman?

(11) This was even more to my taste, for I had an instinctive liking for Frenchmen, and was anxious to see as much of them as possible.

(12) Their business instincts usually directed industrial endeavor into the most productive channels.

(13) But the story has fed, too, on the incurable snob instinct in the heart of all of us.

(14) Now ordinarily Katherine would no more have bent her ear to this dialogue than she would have peeped into another woman's portfolio; but a catlike instinct glued her to the receiver.

(15) The instinct of benevolence appears to be innate in every kindly nature.

(16) So that if you saw a piece of work finished in gilt-edged order—whether it was a job of leadership, a book, washing dishes, or a sewer cleaned, done *right* and shipshape "and then some," you would instinctively say: "There's been a Princeton man on this job. That's the *Princeton way of doing things.*"

(17) He is a second generation Puritan who satisfies his reformer's instinct by booming Zenith City, and his moral prejudices by being a good boy most of the time and distrusting the bad ones.

(18) Impulsive, politically iracund, often the victim of his vocabulary and his instinct for salient phrases and marrowy nicknames, he sometimes wounded beyond his intention.

(19) On hearing the last word, Dona Ana shivered and instinctively turned to look at the picture in which Roberts had been portrayed dying in the gloomy desert.

(20) With the instinct of a Commissioner of Accounts still upon him, Mr. Fosdick inquires whether we have liquid "spiritual assets" to counterbalance the new forces which he seems to regard as potential liabilities.

(21) As in the case of several other young poets of this war-moment, too much importance has been attached to a pleasant and congenial instinct for making Rhymes.

(22) Yet I have no doubt that, with his instinctive courtesy, he divined the wishes of the family in regard to the newcomer and was, therefore, predisposed in his favour.

(23) As I looked at them, I instinctively summoned to my side the radiant shade of Aurea, for indeed she had seemed made of gold —gold and water lilies.

(24) Most novices have a misguided but unerring instinct for *hard* pipes, and this way trouble lies.

(25) My first instinct is to reach for money.

(26) One morning, as they tell it, depending upon her instinct of time, she rose without consulting her clock (which in fact had stopped).

[1] William McDougall, "An Introduction to Social Psychology," London, Methuen and Co., Ltd., pp. 20–21, 1914.

(27) In choosing a confessed apostleship of Bolshevism as the point of attack, Mr. Gompers evinced his instinct for the jugular vein.

(28) She was a lady by instinct, in short, and Kate's father was—well, otherwise.

(29) Aunt Ella's atavistic instincts had demanded a gas fire in the asbestos hearth as part of the ceremonial welcome.

(30) There is a type of reader who will object to the publication of such a book, claiming that it is merely a text-book based on the "direct method," for those who are cursed from birth with criminal instincts.

(31) For of course it meant only that she felt a woman's instinctive rebellion against all such philosophies.

(32) Instinctively his face resumed its old, mocking mask; there was no other way in which he could keep a hold on self-control.

(33) . . . but partly it was due to that instinct for ordered routine, which in a reputable sphere of endeavor would have made this man rather conventional and methodical in his personal habits.

(34) Just then a murmur came from the dying woman within, and nurse and doctor, moved by professional instinct, stepped softly back to the bedside.

(35) But the child had an instinctive aversion to all savages, or possibly the feeling was derived from her mother.

(36) Why is it, we thought, that one instinctively waves to unknown travellers who pass on train or ship?

(37) They snout out the superficial night life of the city with the unerring instinct of all small towners for the perverse and the vicious.

(38) Vernon had not gone far before he regretted his instinct for short cuts.

(39) John Creddy saw the shadow on her face, the unintentional dilation of her delicate nostrils, the faint puckering at the corner of her lips, and knew with a negro's quick instinct of face reading what it all meant.

(40) For, after all, humanity has an uncanny instinct to avoid truth as long as it can.

(41) I have seen a few cases, and only a few, where the style and the matter were so characteristic that all my literary instincts told me that it was the man himself.

(42) It was Mr. G. K. Chesterton who noted that the American man instinctively removes his hat in an office elevator, as a kind of subconscious tribute to his totems of machinery and commerce.

(43) The rich are instinctively crying "Let us eat and drink; for tomorrow we die," and the poor, "How long, O Lord, how long."

(44) The instinct of patriotism, loyalty and altruism can be stimulated and educated.

(45) The instinct of the race regards intercourse between unmarried persons as immoral and anti-social.

In discussing the word "instinct," Dashiell has said:

> At one time the term has been used with reference to a pattern of activity (*e.g.*, walking, manipulation), at another, with reference to the motivation of activity (*e.g.*, curiosity, pugnacity, parental love), and perhaps most frequently, in a way both descriptive and explanatory. The classic notion of "instincts" as God-given faculties mysteriously implanted in animals to guide them aright has given place to inquiries of more scientific types; but contemporary discussions are remarkable for the amount of misunderstanding and confusion traceable to the vagueness of this one term. Bernard found in the literature 849 separate types of "instinct," which he was able to condense to 325 irreducible ones. As Bohn puts it, "Qu'est-ce que l'instinct? Un mot"; or even as Condillac says, "L'instinct n'est rien."[2]

Now that the psychologists are debating the use of the terms "instinct" and "instinctive," the popular writers have adopted them to describe habits and habitual reactions. They have not been concerned, however, with any questions as to whether the responses under discussion exist at birth, or soon after; whether they are universal in appearance and whether they appear without opportunity to learn, as suggested by Gates.[3] Neither do they apply Dashiell's two queries concerning the nature of the act itself. "Does the activity in question natively *fall into some definite and recognizable pattern?* And further, is it natively *excited into activity by some identifiable particular type of stimulus or situation?*"[4]

[2] John Frederick Dashiell, "Fundamentals of Objective Psychology," Boston, Houghton, Mifflin Co., p. 183, 1928.

[3] Arthur I. Gates, "Elementary Psychology," New York, The Macmillan Company, pp. 115–116, 1928.

[4] John Frederick Dashiell, "Fundamentals of Objective Psychology," Boston, Houghton, Mifflin Co., p. 185, 1928.

SCIENCE SERVICE RADIO TALKS

PRESENTED OVER THE COLUMBIA BROADCASTING SYSTEM

THE SURVEY OF THE CONTINENTAL SHELF

By Commander G. T. RUDE

CHIEF OF THE DIVISION OF HYDROGRAPHY AND TOPOGRAPHY, U. S. COAST AND GEODETIC SURVEY

Writings of the ancients, even back to Noah's memorable cruise, contain warnings of the dangers of the sea. The Psalmist wrote of the perils which beset those "who go down to the sea in ships," having reference undoubtedly to the perils of the surface of the sea—of the wave and of the storm and their devastating effect on the small craft of the ancients. The bottom of the sea, however, with its hidden rocks and shoals holds more of menace to the giant vessel of to-day than does the storm. Yet even these are being rendered harmless before the advance of science. The scientist is making the bottom of the ocean echo its whereabouts back to him afloat on its surface, and accurate marine surveys based on the scientific principles involved are robbing the sea of its hidden mysteries.

Early in the history of this country, President Jefferson, recognizing the need for accurate surveys of our coast, inaugurated the organic act passed by the Congress in 1807 for the establishment of the Coast Survey, the oldest scientific bureau in the United States Government.

The intervening century has seen a marked increase in its activities and today its operations extend half way around the world and from the Arctic Ocean to the Equator—from the Philippine Archipelago to Porto Rico and from Alaska to the Caribbean Sea.

The bureau's work is not spectacular and therefore draws little public attention. Many of you probably are not acquainted with its operations. The results, however, exemplified in the nautical charts, open our ports to the armadas of commerce, affecting directly or indirectly the well-being of every citizen. They guide the mariner through safe lanes and warn him of unseen rocks and shoals that might bring him to grief.

The brevity of this history is indicative of the brief manner in which it will be possible, in the time allotted, merely to touch upon one of the many varied activities of this bureau—the survey of the continental shelf.

It may be well first to sketch briefly a description of the continental shelf before describing its survey and the unique methods employed. It may appear to us when visiting the beaches that the edge of the continent is represented by the shore where sea and land meet. Farther seaward, however, extends a gently sloping submerged plain, over which the water gradually increases in depth to six hundred feet at the actual edge of the continent where it begins to dip sharply to ocean depths. This submerged area is known as the continental shelf, and its average width along the coast of the United States is about sixty-five miles. Its outer edge lies only ten miles offshore at Palm Beach. This distance, however, gradually increases northward, and in the vicinity of New York, it is one hundred miles, and off Nantucket Island, two hundred miles.

In general, this plain is composed of material washed down from the land and is of a gently rolling character, but that part known as Georges Bank, extending

as a huge tongue two hundred miles off the coast of Nantucket Island, has the characteristics of a terminal moraine, with its shoals and hummocks of glacial material.

For the probable formation of this offshore bank, we must go back to a period before the dawn of history, except as written in the rocks by the hand of nature. Geologists have read this rock-hewn history written by nature's forces; they tell us that during the Glacial Period, or the Great Ice Age, the northeastern states were covered by great ice sheets extending as far south as the State of New Jersey and offshore to the outer edge of Georges Bank. As this great ice mass ploughed its way southward and finally melted with the coming of a warmer geologic period, it left its mass of débris gathered in its slow march to the sea. To this is attributed the hummocks, characteristic of the shoal area comprising this offshore bank.

I have described in some detail that part of the continental shelf known as Georges Bank, because the Coast and Geodetic Survey is now engaged on a survey of that area, which is twice the size of the state of Massachusetts. This survey was started in the spring of 1930 and will be completed in the fall of 1932.

The purpose of this project is to modernize the nautical chart, through the resources and methods of modern science, to meet requirements of the navigator of the large vessel of to-day, equipped with the efficient navigational appliances now available. The navigator of the past was compelled at times to grope his way with only the knowledge that he had a sufficient depth of water under his vessel. The nautical chart of to-day, however, must supply him a wealth of detail of submarine valley, plateau or mountain range, for with his "echo sounding" apparatus he has the means of obtaining, at full speed, a continuous record of these submerged features under his ship. He is thus furnished a useful aid in the determination of his position in thick weather, when celestial bodies are not available for that purpose.

An interesting result of this survey was the discovery of a submarine valley extending back into the continental shelf on the southeastern edge of the bank. It was discovered by the Survey ship *Oceanographer*, formerly the yacht *Corsair II*, a gift to the government from Mr. J. Pierpont Morgan. As a tribute to this trim vessel, now engaged in charting the ocean she sailed for many years as a pleasure craft, the valley has been named *Corsair Gorge*.

This valley, probably a great gash left by a giant landslide of the glacial material, is two miles wide, eight miles long and eighteen hundred feet deep. This material, having slipped from its insecure hold onto the side of the continent, probably now lies at a depth of six thousand feet just off the edge of the bank. The valley is adjacent to the northern steamer tracks between New York and European ports and with their echo-sounding apparatus furnishes navigators of the liners an excellent additional aid in finding their positions during the thick weather so prevalent in this region.

This echo-sounding device, called a fathometer, is also used by the marine surveyor for determining the depths which appear on the chart in their correct positions relative to each other and to the continent, for the nautical chart is a miniature representation, on a plane surface, of the oceans and the adjoining land masses. The fathometer, briefly, is composed first of an electrically-controlled hammer which, upon striking against the inner steel plate of the vessel's bottom, generates sound waves in the sea water. These vibratory waves travel to the ocean's floor, from which they are reflected as an echo back to the ship and are received by a hydrophone, or sensitive mechanical "ear" fastened

against the ship's bottom, the second unit of the fathometer.

After receipt in the hydrophone, the vibrations are amplified and passed on through electric wires to the indicator, the third unit of the fathometer, in the pilot house. This indicator automatically translates into depth the time required for the sound to travel to the ocean floor and to return as an echo, and also indicates this depth in fathoms by a flash of light on a graduated dial. By means of this sensitive instrument, a vessel at full speed obtains a sounding every few seconds, even in great depths.

Before the world war a deep sounding in the ocean was obtained by reeling out over a measuring sheave piano wire to which was attached a spherical shot, weighing about a hundred pounds. Over an hour was required to take a sounding of 20,000 feet. A sounding in this same depth can to-day be made with the fathometer in exactly eight and one third seconds.

The scientist, having developed this supersensitive instrument for obtaining measurements of ocean depths, has also devised a means of locating these soundings because, to be of any value in the construction of a nautical chart, their positions must be determined relative to the continent as well as to each other. This method for accurately locating soundings, known as radio acoustic ranging, is based upon research work during the world war for detecting hostile submarines. Like the fathometer, this operation, too, is dependent upon a knowledge of the velocity of sound in sea water, which has been determined to be a little less than five thousand feet per second.

In the case of this particular survey of Georges Bank, a number of buoys are anchored along the ridge of the bank in about two hundred feet of water so as to form a chain of triangles with sides ten to fifteen miles long, a buoy at the vertex of each triangle. A station ship is anchored near a buoy at one end of this chain, and by means of a series of observations on the stars, this buoy is located within a probable error of only about 400 yards—not so bad when one considers that it is two hundred miles beyond the sight of land.

The next step is the location of the remaining buoys of the chain relative to this end buoy. The station ship, anchored near the end buoy, has a hydrophone suspended under the keel and connected by wires with the radio set. The mobile survey vessel now steams over to the nearest buoy and, passing closely, drops a depth bomb composed of a quantity of T. N. T. The vibration caused by this explosion travels through the water to the hydrophone of the station ship, and its receipt is automatically and instantly flashed back to the survey vessel by radio. The elapsed time between the explosion at the buoy and the receipt at the hydrophone of the station ship is recorded within one hundredth of a second on a specially-constructed chronograph on the survey vessel. This procedure is followed at all the buoys and, with a knowledge of the velocity of sound in sea water, the distances between all buoys are determined and their positions thus located on the survey sheet.

It is positively uncanny to watch the time of the explosion recorded automatically on the chronograph, and again in ten to fifteen seconds to see, on the same instrument, the times of the receipt of the sound at the hydrophones of the station ships miles away.

The positions of all the survey buoys having thus been determined, two station ships can now be anchored at any two of the buoys and the mobile survey vessel steamed along on a system of sounding lines through fog or into the night, a depth bomb being dropped every ten minutes and thus positions obtained while underway in a manner similar to that used for locating the buoys. Some

of the sounding lines extend to the thousand fathom curve, out beyond the edge of the continental shelf, yet the sound from these explosions travels through the water forty or fifty miles back to the station ships anchored on the bank, and their arrival is flashed back through the night to the survey vessel.

To-day such operations are taken as a matter of course in scientific progress. But two hundred years ago these scientists would have been burned at the stake!

METALS IN THE USE OF MAN

By Professor C. H. DESCH

UNIVERSITY OF SHEFFIELD, NON-RESIDENT LECTURER IN CHEMISTRY, CORNELL UNIVERSITY

It is difficult for us, living in a world or railroads, of steel buildings and ships and of automobiles, to picture a time when man lived without knowing of the existence of metals. Yet for very many thousands of years the men of the Stone Age used only stone, wood and bone for their tools and weapons. The first metal that became known to man was gold. Unlike iron and copper, it does not have to be smelted from an ore, but may be found in the beds of rivers, conspicuous by its bright yellow color among the dull sands and gravels. Primitive men and women loved to decorate themselves, and this bright metal, soft enough to be hammered out into thin sheets, lent itself wonderfully to the making of gay ornaments. Later, as skill increased, it was worked into the most exquisite forms of flowers and fruits to make the head-dresses of queens, such as have been found in Mesopotamia and in Egypt and may be seen in our museums.

Copper and silver followed next. Like gold, they may be hammered out on a stone anvil with a stone hammer, but unlike it they tarnish in the air, so that the lumps found in nature are dull and not brilliant as is gold, making it more difficult to recognize them when they occur. Masses of copper up to thirty pounds or more in weight were hammered to shape by the mound builders of Ohio (to be seen in the museum at Columbus), and the men of even earlier times used the same means. It is only in a few regions, however, that copper is found as a metal, and usually it has to be smelted from its ores. Probably the discovery of smelting was accidental. Stones were used to build up the primitive fireplaces, and when it had happened that among those stones the bright green ore of copper had been used, a lump of metal would be found among the ashes and could be hammered into a tool. When some observant person noticed this fact the art of smelting was born.

In Asia, the art of working copper reached a high pitch, and copper tools, such as knives, were made by hammering the metal to a sharp edge, making it hard enough to use for cutting. It is sometimes thought that the ancients possessed some secret for hardening copper, but this is not so. The microscope tells us how their tools were forged, and we can obtain just the same hardness at the present day by the same means.

Then came a remarkable invention, that of bronze. Copper can not be made very hard, however much it is hammered, but when it is melted with tin, or when ores of copper and tin are smelted together, a very much harder alloy, bronze, is obtained. This alloy, too, can be cast into shape in stone or clay molds. How this discovery came to be made is still a mystery. The ores of tin are not brightly colored, like those of copper,

and they are much less common. Somehow it was found that this alloy was better than copper, which it soon replaced. Even in the earliest graves of Ur, in Mesopotamia, which probably date from 3500 B. C., most beautiful objects of bronze are found together with those of copper. The Sumerian artists had wonderful skill in the working of metals as well as in that of wood, bone and ornamental stones.

Iron, the commonest of our metals today, was not used until long after bronze. Perhaps we may take about 1500 B. C. as the earliest date of its introduction. This may seem strange, but the lateness of its discovery has a simple cause. An open fire will melt copper or bronze easily, but even when burning fiercely in a strong wind it will not melt iron or steel. Smelting the ore in a fire yields a dirty, spongy lump, hardly recognizable as a metal. By careful heating and forging it can be made firm and compact, but this was only discovered late. Once the art had been mastered, it was found that iron made much stronger tools and weapons than copper or bronze, and its use soon spread. It may well be that the smelting of iron was first discovered in Central Europe, and that the art spread eastwards before the West learned anything of it. Certainly the Persians and Indians became masters of it, and the beautiful swords and armor which they made still excite our admiration.

It is true that we occasionally find objects of iron of much earlier date. For instance, the first graves at Ur have yielded a small axe, probably for ceremonial use, which is of iron, and a few other very early iron objects are known. But when we examine them by chemical analysis and by the microscope, we find that they were not smelted from ore, but were hammered out of pieces of meteorites, as some of the Eskimos make knives at the present day. As meteorites—lumps which appear as shooting stars and occasionally fall on to the earth from the sky—are not common, these iron objects were very precious, and we know from ancient writings that iron, before it came into common use, was prized above gold.

Although iron was used where hardness and cutting quality were important, bronze continued to be made, and some of the most beautiful of bronze objects belong to what we call the Iron Age. Silver, lead, and tin were also used, but were never so important as iron and bronze. Steel differs from iron in being harder, but it is made in the same way by heating longer in the charcoal fire. Steel is made much harder by quenching when very hot, and we find this process clearly described in writing as far back as Homer.

The Greeks and Romans brought to still greater perfection the arts of working metals practised by the Sumerians and the Egyptians, especially in the casting of large statues of bronze. The earlier bronze statues were made of hammered plates fitted on to a core of wood, but by casting much more magnificent work could be executed.

All down through the Middle Ages there was little change in the methods of working metals. In Europe and in Asia alike there were many craftsmen, and much of their finest work survives to this day. Water-power for blowing the furnaces took the place of natural draft or hand bellows, so that larger quantities could be melted, but for many centuries there was little change in the processes. In the 18th century came one of the great changes, the use of coal in place of charcoal in the smelting of iron, followed by the invention of many new processes. It was these inventions that made the steam engine possible, inaugurating what we call the industrial revolution.

It is impossible to speak to-day of progress in the 19th century. Such in-

ventions as those of Bessemer changed the scale of production so that iron and steel, made 150 years ago in quantities measured by a few thousand tons, increased to their present production reckoned in scores of millions of tons. Our modern industrial civilization is based, not as sometimes imagined on gold, but on iron. Iron and its variety, steel, make possible our means of transport and the whole mechanical basis of our industry and life. The steel of to-day, however, is very different from that of the time of Homer. Means have been found to make it harder, tougher and stronger by special treatment, or by alloying it with other elements, some of them, such as vanadium and molybdenum, being rare metals which only a few years ago were merely chemical curiosities. Besides steel, new metals and alloys have entered industry—metals quite unknown to our forefathers. Chief among these is aluminum, a metal distributed widely in the earth, but needing such special means for its extraction that it remained unknown until our own time. Suitably alloyed and treated, it has properties rivaling those of steel.

The arts of peace and of war depend upon metals, and both have contributed to the progress of their production and working. The automobile and the airplane, with their high speeds and need for lightness, have perhaps done most to improve modern metals and alloys. Every year sees fresh progress in the field of metallurgy, and there is hardly any branch of the history of civilization more fascinating than that which tells how man has advanced from the Stone Age to the Metal Age of to-day, with its highly developed industries and complex organization. Would that we had been as successful in solving the problems of human relations as we have been in adapting the metallic riches of the world to human use!

ODDITIES OF THE OCEAN

By Lieutenant-Commander R. R. LUKENS
CHIEF, COAST PILOT SECTION, U. S. COAST AND GEODETIC SURVEY

WHEN you make a sea voyage on one of the many cruises which are so popular this winter, you may look across that apparently limitless expanse of ocean and decide for yourself, at least, that it certainly is one monotonous part of the world. If it be a bit rough and something you ate for lunch does not seem to set well on your stomach, you might even have a worse opinion of Father Neptune's domain.

To the oceanographer and hydrographic engineer, however, the sea and its mysteries are extremely interesting, and the floor of the ocean appeals to them as a great field for exploration. The bottom of the sea is the one place left that no one has ever seen—unless we except the biblical story of the children of Israel crossing the Red Sea—but still the hydrographic surveyor by taking accurate soundings and bringing up specimens of the bottom can produce a rather accurate map of it and give us considerable information concerning it.

This afternoon I would like to tell you of some queer things that officers of the Coast and Geodetic Survey have found in their 115 years of surveying our coastal waters.

First there is the remarkable submerged canyon of the Hudson, which lies about 50 miles at sea off the entrance to New York Harbor. If you take a chart of this section of the coast you can easily trace, by the deeper soundings, what geologists tell us was undoubtedly the course of the Hudson

River millions and millions of years ago before the eastern seaboard subsided and brought the shoreline to its present location at Sandy Hook and Coney Island. After following this ancient submerged valley for about 50 miles from Sandy Hook, we come upon a canyon which approaches the Grand Canyon of the Colorado in magnitude. Soundings show that the canyon at one place is more than 2,400 feet deep and about three miles wide from rim to rim. This grand gorge extends for about 20 miles until it spreads out fan-like and merges with the bottom of the sea. What grand scenery this canyon would make, but there seems to be no hope that any of us will ever get to see it. The canyon and old river valley serve one useful purpose, however, in that they form under-water landmarks for vessels equipped with echo sounding apparatus. In the case of a vessel bound from the Delaware Capes to Boston in foggy weather, the soundings tell the navigator when he is crossing this gorge and by referring to his chart, he can spot his position with entire confidence.

When Ponce de Leon was sailing along the Florida coast in search of the fountain of youth, he unknowingly sailed right by such a fountain two and one half miles offshore and nine miles south of the old city of St. Augustine. Here we have the unusual feature of an oceanic spring sending up millions of gallons of fresh mineral water from the sea bottom at a general depth of 55 feet. The bubbling up of this water produces a marked effect on the surface and it can be seen for a distance of one mile. A strong odor, quite similar to the sulphur springs of Florida, can be detected under favorable conditions when two miles away.

The water comes up with considerable force and creates such swirls that the officer who investigated it reported that it was very difficult to hold a boat over the spring. If the outlet of this spring were on land it is probable that it would resemble a geyser more than a spring. The spring emerges from a hole only about 25 feet in diameter and 125 feet deep, or 70 feet below the surrounding ocean bed.

Not to be outdone by Florida, California boasts of oil springs adjacent to her southern coasts. One of these is in the southern part of Santa Monica Bay near Redondo, and is located near the head of a deep submarine valley which makes in from sea. The oil comes up from a depth of 75 fathoms with sand and green mud bottom and covers a considerable area. Years ago when there was great rivalry between Redondo and San Pedro as to where a harbor should be built, Redondo used the oil spring as an argument in its favor, claiming that the oil produced by the spring would form a "slick" and in time of storm tend to keep the harbor entrance smooth. Apparently the Government engineers were not impressed, for the harbor was built at San Pedro, and is now known as Los Angeles Harbor. The oil spring was known to mariners many years before the oil prospector appeared on the scene and brought in the great oil fields that to-day exist in this vicinity.

Another oil spring occurs in the Santa Barbara Channel, a short distance west of the city of Santa Barbara. Here the smell of petroleum was so strong that the adjacent point was named "Coal Oil Point." Professor Davidson, who made the early surveys, stated that the smell of petroleum was almost overpowering and penetrated every part of a steamer which required about ten minutes to run through the coal-oil laden atmosphere.

You perhaps know that besides giving the depths of the water, the nautical chart shows the character of the bottom. Thus in looking over a chart will be seen abbreviations for mud, rock, sand, shells, etc., which indicate the kind of

bottom in that vicinity. While the survey is being made the sounding lead is armed, as we call it, with tallow and after the sounding is made and the wire reeled in, the lead is examined to see what it has brought up.

At one place in Alaska, the chart shows gold dust as a bottom characteristic. This occurs about 18 miles southeast of Juneau in Stephens Passage and at a depth of some six hundred feet. Many prospectors have looked with greed at this indication of gold, but no one has ever yet devised a machine for dredging at such a great depth.

A curious feature of the waters of Alaska is the pinnacle rock. These lurking dangers often extend to within a few feet of the surface and have been the cause of many a shipwreck. The menace of these pinnacles was so great that the main ship channels of Southeastern Alaska have been swept by the wire drag and the pinnacles thus discovered are now charted.

One remarkable pinnacle was found which rose from a general depth of 600 feet to within 17 feet of the surface. This pinnacle is higher than the Washington monument, and, in fact, has been called the "Washington Monument Rock." It is fortunate that it was discovered by the wire drag before some unlucky ship struck it. In 1929 a large passenger vessel in western Alaska struck a charted pinnacle rock and went down in about seven and one half minutes. Only quick work in launching the life-boats averted a great loss of life.

In addition to her many high and spectacular volcanoes on land, Alaska has the very strange phenomenon of a submarine volcano. This is known as Bogoslof and is located in Bering Sea about 60 miles west of the village of Unalaska, and some 25 miles north of Umnak Island. It is out of the line of traffic and is only visited by an occasional cutter on patrol duty. Bogoslof rises up from depths of nearly 6,000 feet. It throws up islands and then blasts them away with terrific explosions. Nearly every year there are great differences in the appearance of the island. It is so seldom visited that no doubt many eruptions have gone unrecorded, but we know that great convulsions occurred in 1796, 1883, 1906 and 1910. The eruption of 1910 was witnessed by the officers of the *Tahoma*, who reported a column of steam and ashes many thousands of feet high. Of recent years great changes in the topography of Bogoslof have been reported, but no violent eruptions have been recorded.

Now and then we read stories of great changes in the ocean bed, islands disappear, rocks are shoved up and changes are reported in depths. Except for such localities as Bogoslof and where rivers discharge their load of silt and sand into the sea, the Coast and Geodetic Survey has seldom found any evidence of these changes.

One notable exception, however, occurred in the Sulu Sea in the Philippine Islands. In 1914 this area was surveyed by the Coast and Geodetic Survey, using standard methods of hydrography. A bank or shoal was found which was about two miles long and some half mile wide. This bank was carefully sounded over with closely spaced lines; depths of eight to ten fathoms with sand and coral bottom were found over the crest of the ridge.

Two years later, the surveying vessel under my command was instructed to do some supplementary sounding in this region, and in doing so, I ran a sounding line over this previously surveyed bank. We picked up the north end of the bank and our soundings agreed perfectly with the old work. Suddenly, when nearly half way over the bank, the Filipino leadsman sang out, "Twenty fathoms and no bottom." I thought the man had suddenly lost his mind, for I did not see how such a depth could pos-

sibly exist. I stopped the ship and took a cast with the sounding machine, and sure enough the depth was 32 fathoms; and this at the point where the previous survey showed ten fathoms! We went ahead and resurveyed the bank and found that while both ends were the same, the central part had sunk and that there now existed a 30-fathom channel between the two ends.

The two surveys were of equal accuracy and neither could be questioned, so that we could only assume that the central part of the bank had sunk or caved in to the extent of 20 fathoms, or 120 feet. No such vertical movement on land has ever been known even at the epicenter of the most violent earthquakes. What caused the subsidence, nobody knows. The records show that in the interim between surveys a severe earthquake had occurred in the vicinity and it may have been the cause, but there is no proof. This is the only case in which the Coast and Geodetic Survey has undisputed proof of a major change in the sea bottom.

While we are on the subject of the Philippines, you might be interested in knowing that the deepest sounding ever made in any ocean was had in 1927 by the German cruiser *Emden* at a point about 45 miles east of the Island of Mindanao in what has long been known as the "Mindanao Deep." The depth here was found to be 35,400 feet, or 6.7 statute miles. This spot is only 75 miles from a mountain 6,027 feet high; so we have here a difference of elevation of over 41,000 feet, which is 12,000 feet greater than the height of Mt. Everest, the highest mountain in the world.

The German vessel used echo sounding in determining the depth, but wire soundings have been made in depths of over 30,000 feet. Many people have the impression that, due to the enormous pressure, a weight will not sink to the great depths of the ocean. This is not the case. A cast-iron shot on the end of a piano wire, such as is used in deep sea sounding, will continue to go down until the bottom is reached. Due to the friction of the wire passing through the water, however, the wire pays out very slowly and it is difficult to tell the instant when the shot has reached bottom. Once the shot strikes bottom it is detached and the rod only is hauled back. A specimen of the bottom brought back in the hollow rod is proof that bottom was actually reached.

The Coast and Geodetic Survey is frequently called upon to search for what often proves to be phantom rocks. Lenard Rock in the North Pacific was such a case. Many years ago this rock was reported by sea otter hunters who claimed they had actually made fast their bidarkas to it. Later the captain of a trading schooner reported that he had lain becalmed in plain sight of the rock which was in the path of vessels bound from Seattle to Bering Sea.

If this rock really existed, it was a danger of the first magnitude, and every effort was made to verify the reports. Commercial vessels looked for it in clear weather, Government vessels were always on the alert for it and the Coast and Geodetic Survey spent several seasons making systematic surveys in the locality.

Lenard Rock was never found, and the evidence against its existence seemed so strong that it was taken off the charts and now the sea captains of a younger generation, unaware of the story of Lenard Rock, sail blithely by without thought of danger.

"GENES"—THE UNITS OF HEREDITY

By Dr. FRANK F. BUNKER

EDITOR, CARNEGIE INSTITUTION OF WASHINGTON

RECENTLY the interest of the scientific world was aroused by the announcement that Dr. John Belling, cytologist of Carnegie Institution of Washington, had actually seen the ultimate physical units of heredity in the cells of the lily, had counted and photographed them, and had observed somewhat of their behavior.

Until this announcement was made no one has thought that a *gene,* as the unit is called, had ever been seen. Like atoms, the existence of such entities has been inferred. A century ago, in attempting to explain the chemical behavior of substances, scientists found it necessary to assume the existence of atoms. All that has since been learned about the nature of matter seems well explained on the assumption that atoms exist.

So in biology, the results obtained from countless experiments in breeding plants, insects and higher animals can best be explained by assuming that genes actually do exist, that they are located, as separable particles, at definite and constant places in the *chromosomes* (carriers of heredity), and that these genes are responsible for those hereditary traits which distinguish one species from another and one individual from another.

HEREDITY VERSUS ENVIRONMENT

Ever since Carnegie Institution of Washington was established, twenty-eight years ago, its department of genetics has had investigators at work in study of the rôle which heredity and environment play in the life of plants, insects and higher animals, including man. As a result of their investigations and of those made by biologists working under the auspices of other agencies general agreement has been reached that every plant and animal is the product of two interacting influences.

One influence is the sum total of the internal factors that direct the development of the individual. This is heredity. The other influence is the sum of the environmental factors that determine the way in which the internal factors are able to express themselves in the development of the organism.

The actual appearance of an individual is the response of these internal factors to environment. Change in environment may modify the appearance of the individual to a greater or less degree; *i.e.,* its sum total of inherited factors respond differently to the surroundings.

In speaking of these matters and of their implications Dr. C. B. Davenport, director of the Institution's Department of Genetics, says:

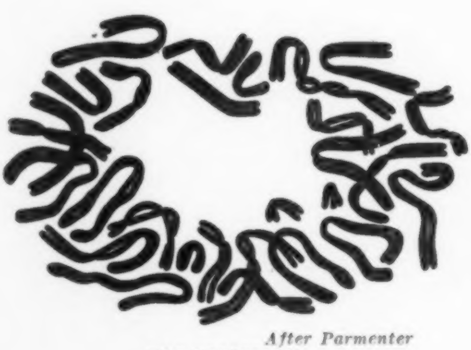
> The thoughtful person can never cease to admire the wonderful way in which the world of natural objects is reproduced generation after generation. We wonder, on the one hand, at the great diversity of species; on the other, at the marvelous precision with which each species is reproduced. We marvel, also, at the wonderful fitness of organisms to the world in which they develop and, in turn, reproduce.
>
> It is for the geneticist to give a scientific explanation of these phenomena, to bring under general laws the isolated facts of development, of diversity, of fitness.
>
> The first great advance in the scientific explanation of these phenomena was the tracing of the development of the individual by embryologists. The next was the discovery of the mechanism by which the internal factors that control development do their work. It is because the germ plasm—the chromosomes and their constituent genes—shows a continuity that the species reproduces itself. It is the failure of the former germ plasm to continue to reproduce itself in the same old way that is responsible for genetic variation or mutation. Yet

After Painter
MAN

After Mann
GRASSHOPPER

After Metz
HOUSE FLY

After Painter
HORSE

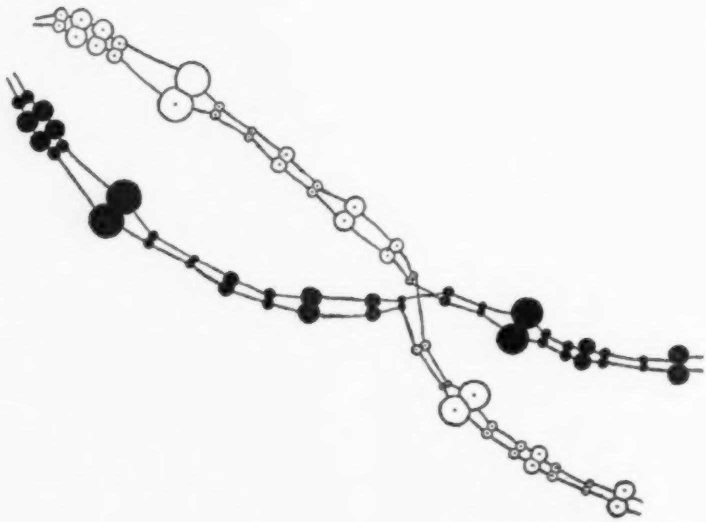


After Parmenter
SALAMANDER

After Mann
PLANT—(*Crepis*)

DRAWINGS OF CHROMOSOMES OF VARIOUS ORGANISMS

AS SEEN UNDER THE MICROSCOPE, GREATLY ENLARGED. CHROMOSOMES ARE STRUCTURES IN THE CELLS OF LIVING THINGS WHICH, THROUGH FERTILIZATION AND CELL DIVISION, PASS FROM PARENTS TO OFFSPRING. EACH CONSISTS OF A GREAT NUMBER OF GENES STRUNG TOGETHER IN A SINGLE ROW LIKE BEADS ON A STRING. THE DEVELOPMENT OF THE INDIVIDUAL, IT IS THOUGHT, IS BROUGHT ABOUT THROUGH THE INTERACTION OF THESE GENES. EACH SPECIES OF PLANT AND ANIMAL HAS A CONSTANT AND TYPICAL NUMBER OF CHROMOSOMES: MAN AND THE MONKEY HAVE 48; THE FROG, 26; THE PIGEON, 16; THE HORSE, 60; THE FRUIT-FLY, 8; THE HOUSE-FLY, 12; THE LILY, 24.



Drawing by John Belling

DIAGRAM SHOWING "CROSSING-OVER"

DIAGRAM, AFTER A CAMERA DRAWING, OF THE SEPARATION OF A SMALL PART OF THE DOUBLE CHROMOMERE STRINGS IN FRITILLARIA LANCEOLATA, SHOWING THAT THE TWO PARENTAL CHROMOMERE STRINGS (NOW BOTH DOUBLE) SEPARATE, AT FIRST IN MANY PLACES, LEAVING NODES BETWEEN. IN THIS CASE THEY HAVE "CROSSED-OVER" (EXCHANGED PARTS) AT THE NODE. DR. BELLING BELIEVES THAT JUNCTIONS OF THE CHROMOMERES AT A BEND, A CROSS, A TWIST, OR AN OVERLAP IN THE CHROMOMERE THREADS ACCOUNT FOR THE VARIOUS PHENOMENA CONNECTED WITH GENE BEHAVIOR OBSERVED BY GENETICISTS.

just that failure is regular; and the laws determining it are the subject of our investigation.

DR. BELLING'S DISCOVERY

For a number of years Dr. Belling has devoted all his time to research on the mechanism of inheritance believed to lie within the microscopic bodies called *chromosomes* which occur in the nucleus of every living cell. His investigations have taken him into study of the principles of optics as they apply to extremely high-power microscopes, into search for plants having chromosomes which could be studied to best advantage, and into development of an improved technique in preparing chromosomes for observation.

He found that plants of the lily family were especially suited to his purpose because in them the essential structures are more widely separated than in other plants. The Easter lily, the Madonna lily, the royal lily and the leopard or tiger lily of California were the members of this family which he most frequently examined; but it was in the last of these that he first observed the objects which he believes contain the genes.

Although, according to theory, genes are present in the tissue cells of plants and animals as well as in their germ cells, it is with the latter, more particularly the pollen mother-cells of the flower buds of the lily, that Dr. Belling works.

He takes the anthers (pollen-bearing flower parts) when they have reached the proper stage of development, cuts them open and presses the mother-cells of the pollen out on to a clean glass slide which he instantly immerses in a fixing solution consisting of a combination of powerful chemical agents. It is important, he finds, that the cells be killed instantaneously; for if they are permitted to die slowly the structures which

he wants to observe fuse and lose their distinctive appearance.

Having thus completed the preliminary preparation, he subjects the slides to treatment with various staining solutions which the cell structures absorb in differing degree, thereby making them more easily distinguishable under the microscope.

So skilful in manipulating these diminutive pollen mother-cells has Dr. Belling become, and so successful has he been in finding dyes which give maximum visibility, that even though the cells themselves are less than one four-hundredth of an inch in diameter, a size which is below the limit of unaided human vision, yet in these tiny containers he has seen and counted at least 2,200 different bodies which he thinks are the ultimate units of the inheritance mechanism.

In the living plant, Dr. Belling states, a coat of stainable matter forms around the genes so thick and viscid that it can be pulled out into long strings. A gene with its coat of stainable matter is called a *chromomere.* Each of the strings of *chromomeres,* of which there are 24 in the tissue cells of the lily, constitutes a *chromosome.*

Dr. Belling has counted the *chromomeres* in the lily and showed that each contains a single core which is barely visible when conditions are most propitious; that these are plentiful enough to satisfy the theoretical requirements of gene numbers; and that the various phenomena connected with gene behavior, designated by geneticists as "crossing-over," "inversion," "translocation," "deletion," and "deficiency," can be accounted for by junctions of the *chromomeres* at a bend, a cross, a twist or an overlap in the chromatin threads.

Importance of the Gene

In commenting upon the function of these structures, Dr. Belling says:

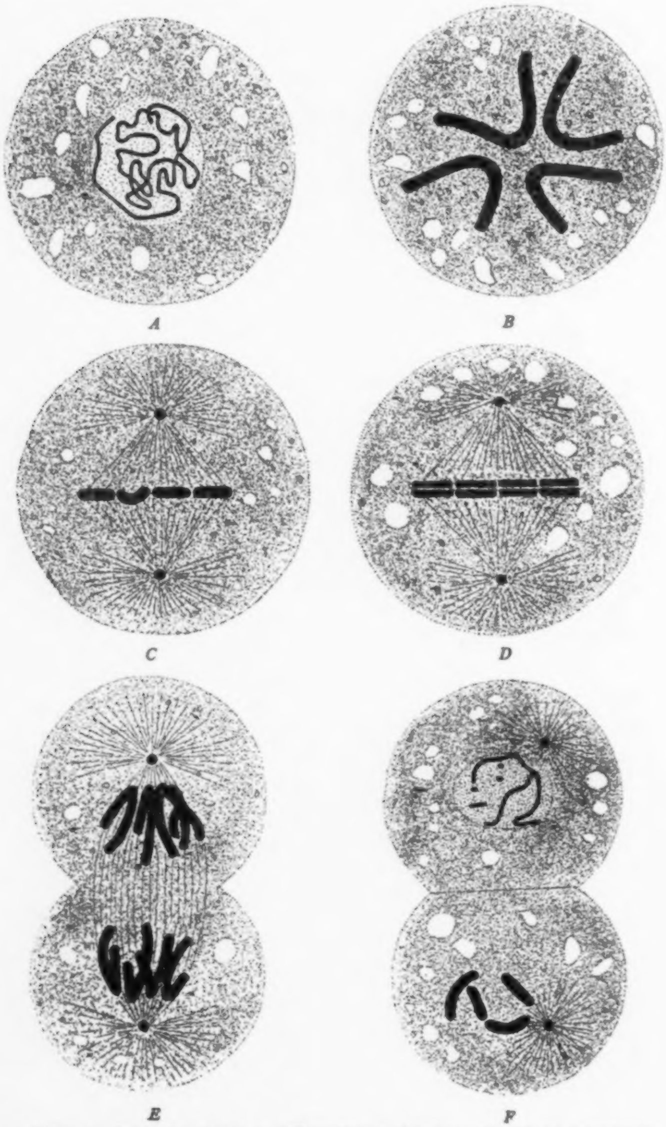
> A minute cell sphere with its 2,200 gene pairs suggests the celestial sphere visible to the unaided eye and containing fewer than 3,000 stars which can be seen at one time. These stars were supposed by some to exert a mystic influence on human beings. In the spherical cells of the organism, however, the genes actually do exert specific influences on the life of the organism in question, whether of the lily or of man. In fact these influences are so great that if the effects of all the thousands of genes in a given organism were added together nearly the whole of its inheritance would be accounted for.
>
> These strings of chromomeres are of more consequence, therefore, than the threads of life which, according to the old fable, the Fates were supposed to spin. Indeed, in many of the old sayings relating to the influence of the stars, if the term "gene" or "chromomere" be substituted for "star" the saying would hold to-day. Could we but identify every one of the chromomeres in a man (probably there are many more than in a lily), a reliable horoscope for him could be drawn up.

The relevancy of Dr. Belling's remarks concerning the influence of genes or chromomeres in heredity will become apparent when it is realized that the method by which the cells of plants and animals divide is such as to make certain that genes from both the parents are transmitted to the offspring. A quick review of the description which cytologists give of the basic features of the method will make this clear.

The Forming of Chromosomes

Nearly all living things begin with the fusing of two sex-cells, one from the male and the other from the female. This is fertilization, whereupon development begins. The single fertilized cell thus formed divides into two cells, these into four, the four into eight and so on until, in time, there are millions of cells organized, in the case of plants, into roots, stalks, leaves, flowers; and, in the case of animals, into bones, muscles, blood, heart, brain and all the other tissues of the animal body.

In one respect the living cells, whether of plant or of animal, are all alike—they are filled with water and, moving



After A. Franklin Shull in "Heredity," McGraw-Hill Book Company

STAGES OF CHROMOSOME DIVISION

SHOWING THE STAGES THROUGH WHICH THE CHROMOSOMES OF ASCARIS, A PARASITIC THREAD WORM, PASS WHEN CELL DIVISION TAKES PLACE. DRAWINGS OF ACTUAL SPECIMENS CUT IN THIN SECTIONS. *A*, EARLY STAGE, CHROMATIN THREAD SLIGHTLY CONDENSED; *B*, CHROMATIN THREAD HAS FORMED INTO CHROMOSOMES WHICH ARE ARRANGED ACROSS THE MIDDLE OF THE SPINDLE; *C*, SAME AS PRECEDING, VIEWED FROM THE SIDE OF THE SPINDLE, WITH CHROMOSOMES NOT COMPLETELY IN THE SECTION; *D*, CHROMOSOMES SPLIT LENGTHWISE; *E*, CHROMOSOME HALVES MOVING APART, CELL BODY BEGINNING TO DIVIDE; *F*, DIVISION OF CELL BODY COMPLETE, CHROMOSOMES IN CELL AT TOP BEING RECONSTRUCTED INTO A NUCLEUS.

through it, is a substance called *protoplasm* which holds suspended in it, usually in a central position, a spherical body of somewhat denser material called the *nucleus*. The nucleus is of great consequence, for it is known that it exercises a controlling influence on the physiological activity of the cell. It is also of particular importance in heredity.

When the cell is quiescent the nucleus apparently consists of a tangle of fibrous material. In preparation for cell division these threads appear to shorten and thicken, forming segments, twenty-four in the lily, forty-eight in man. These rod-like bodies in the nucleus, seen at this stage, are the chromosomes.

The Splitting of the Chromosomes

The chromosomes quickly take an orderly position at the middle of the cell, whereupon fibers develop which connect each chromosome with opposite "poles" of the cell.

When this stage is reached each chromosome splits along its length. Thus two sets of chromosomes are formed, each set being a counterpart of the original set. The two sets then pass to opposite poles, drawn there, some think, by the contraction of the fibers, whereupon the cell divides. Two cells are thereby formed, each containing a set of chromosomes which is exactly like the set contained in the sister cell and both exactly like the parent set from which they sprang.

In these new cells each group of chromosomes takes a central position and reforms a spherical nucleus from which, after a resting period, chromosomes again emerge when these daughter cells, in their turn, are ready to divide. Through repetition of this process all the tissues of the individual plant or animal are built up of cells containing chromosomes which are all directly "descended" from those originally present in the fertilized egg.

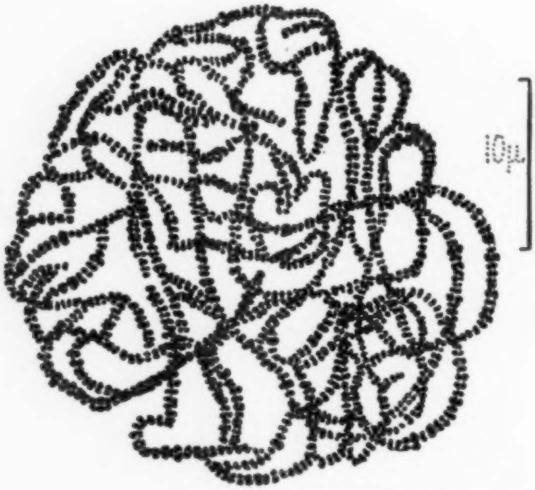
We have said that the process just described is such that a guarantee is had that the cells of the individual plant or animal shall contain all the chromosomes characteristic of the species to which it belongs. This is true of all the cells of a given individual excepting only that group in each instance which is concerned with reproduction. By a striking modification of the process of cell division, the chromosome number in the germinal cells of both sexes is reduced to one half the characteristic number.

Reduction Division in Germ Cells

The reason for this reduction in chromosome number is obvious. If there were no reduction, when the male and female cells unite the fertilized cell would contain double the characteristic number. In each subsequent generation the number would again double and so on indefinitely; thus a wholly absurd situation would soon arise.

As these germinal cells develop, the chromosomes in them come together in pairs while still very thin instead of splitting longitudinally and forming duplicate sets as they do in the ordinary tissue cells. The members of each pair, instead of the halves of each chromosome, separate to opposite poles, whereupon the cell divides into two cells. In this manner the number of the chromosomes is reduced one half, the full number being restored when fertilization takes place.

However, before the cells formed by this process of reduction mature and become capable of functioning in reproduction they undergo one further division which, it should be noted, does not change their chromosome number. That is to say, from any cell that undergoes this reduction division four cells are finally derived. In the male, whether of plants or of animals, all four become sperm cells capable of fertilizing the female. In the case of the female among animals, only one of the four develops



Drawing by John Belling
CAMERA DRAWING OF A CHROMOMERE STRING.

into an egg, the other three remaining functionless and clinging to the side of the egg in the form of small rudimentary cells known as "polar bodies."

Exceptions Noted

Although the foregoing steps in chromosome behavior are sufficiently general among plants and animals to justify the conclusion that they are typical, nevertheless, as investigation continues, significant modifications in the processes are found to exist. These relate particularly to the behavior of the so-called sex-determining chromosomes. Moreover, the work of Dr. C. W. Metz, of the Department of Genetics, on the fungus gnat, *Sciara,* shows that with this genus at least there are peculiarities in chromosome action which put it in a class apart and which open up problems the solution of which may throw much light on uncertain and little understood aspects of the inheritance mechanism.

For the general reader, however, the important things to remember about the basic features are these: that there is a method of cell division common to practically all plants and animals which insures that all the cells of the individual except the reproductive cells shall carry the full number of chromosomes characteristic of the species; that the reproductive cells in each case shall contain one half of the characteristic number (except as modified in respect to the sex-producing chromosome); and that when the fusing of the male and the female cells takes place in fertilization the characteristic number is reestablished.

The most striking feature of cell division, then, is the longitudinal bisecting of the gene strings (chromosomes) and the provision whereby every daughter cell is granted its full complement of these priceless genes, presence of which, according to all available knowledge, is essential to continuity of life, of organization and of species.

Study of the Fruit-fly

The work on the fruit-fly (*Drosophila*), begun by Professor T. H. Morgan, of Columbia University, and continued by him and his students, supplemented by investigations in other institutions, is chiefly responsible for establishing this gene theory of heredity. By breeding, literally, millions of pedigreed flies and observing the results,

Morgan and his students have been able to identify the genes responsible for many of the characters which appeared in the adult flies and to prepare diagrams to show the locations of the controlling genes in their respective chromosomes.

At one time it was thought that for every character appearing in the adult there is a gene to correspond: that, for example, there is a particular gene which controls wing shape; one which determines eye color; another which is responsible for head shape; and so on for all the other characters.

The work on the fruit-fly, and that done in other investigations, however, proved this view to be untenable. It showed, for instance, that red eye color in this fly is the end product of the co-operative action of a troop of genes, of at least fifty in this case; that the wing of the fly is a complex requiring the interaction of hundreds of genes; and that all the other characters are responses in each instance to the influence of many genes.

In turn, each gene may affect many characters. Alter a single gene in a co-operative group and the character which is the result of the interaction of the members of that group will be altered. Thus a change in a single gene in the fruit-fly may rob the eye of all color, giving a white eye, or it may change the typical shade of red to another slightly different. And what is true of the fruit-fly in these matters applies equally well to all other organisms, including man, insofar as they have been studied.

Photograph by John Belling

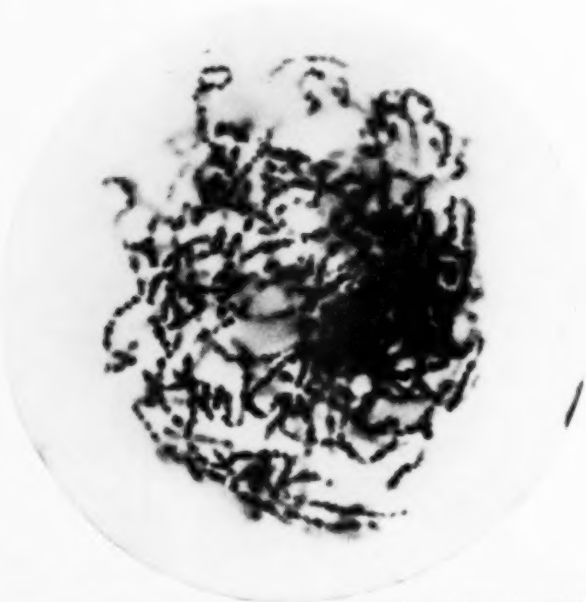
A PHOTOGRAPH SHOWING THE COMPLETE SEPARATION OF THE SPLIT CHROMOSOMES

OF THE TWELVE PAIRS FROM THEIR MATES IN THE LILY. ANOTHER DIVISION FOLLOWS, SEPARATING SIMILARLY THE SPLIT HALVES. THEN GROUPS OF TWELVE CHROMOSOMES ARE READY TO PASS AS PARENT GENE STRINGS TO NEW LILY SEEDS. BY THE INTERCHANGES WHICH HAVE TAKEN PLACE, NOT ONLY HAVE THE TWELVE CHROMOMERE STRINGS OF ONE PARENT BEEN SHUFFLED WITH THE TWELVE STRINGS OF THE OTHER PARENT BUT A SMALL AMOUNT OF SIMILAR SHUFFLING OF THE CHROMOMERES HAS OCCURRED.

Drawing by John Belling

UPPER—A DOUBLE ROW OF CHROMOMERES

IN THE POLLEN MOTHER-CELLS OF ALLIUM (THE ONION FAMILY) AS SEEN UNDER THE MICROSCOPE, GREATLY ENLARGED. THE CHROMOMERES HAVE BEEN SQUEEZED FLAT SHOWING THAT THERE IS AN EXTREMELY MINUTE GENE IN EACH. LOWER—A DRAWING REPRESENTING THE ABOVE DOUBLE STRING OF DEEPLY STAINED CHROMOMERES BEFORE DESTAINING AND SQUEEZING FLAT. THE CHROMOMERES IN MANY PLANTS AND ANIMALS ARE SO SMALL THAT ESPECIALLY ACCURATE MICROSCOPY IS REQUIRED TO SEE THEM AT ALL.



Photograph by John Belling

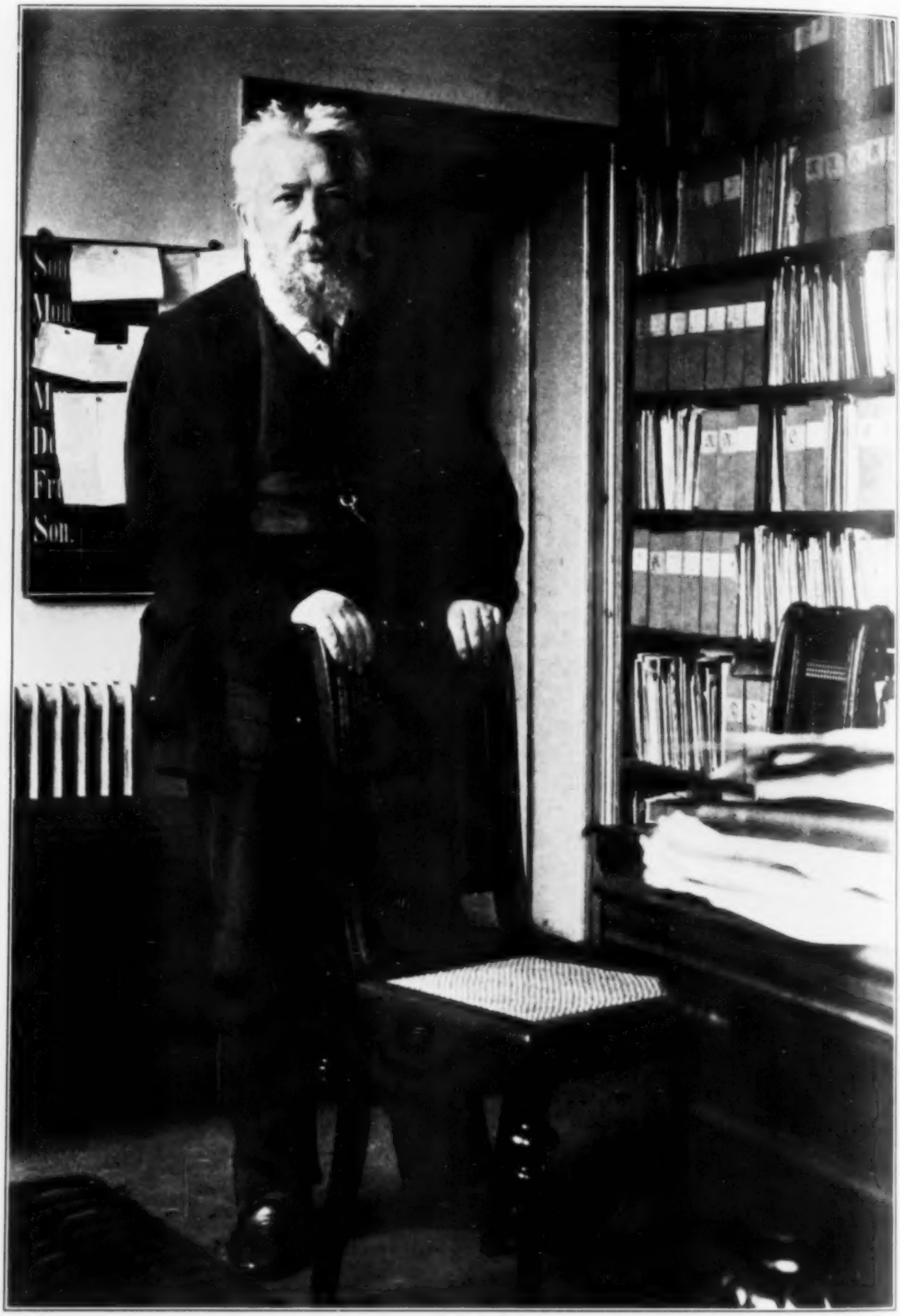
CHROMOMERE STRINGS IN THE LEOPARD LILY.

Existence of Gene Confirmed

In the light of these considerations genes have been compared to discrete packets of different chemical substances (super-molecules, perhaps) bound together loosely into chains. Each chain constitutes a separate chromosome made up of an enormous number of these packets of heredity, 2,200 in all the chromosomes together, Belling says of the lily. Through the various processes taking place in the cell these packets are paired, distributed and reassembled into new combinations, obeying in so doing certain definite laws of heredity.

It would seem, therefore, that explanation of the various ways in which the individuals of a given species develop, whether plant, insect or man, of the peculiarities and diversities that give them individuality, and of the extraordinary resemblances and differences that exist between parent and offspring, requires the assumption that there actually exists a constituent physical entity in the chromosome which is passed along from generation to generation and that this is capable of bringing about the development in the new generation of the same character which its progenitors had developed in the parent generation.

Dr. Belling's announcement that he has seen this ultimate entity; that he has photographed it; and that he has watched its behavior in the several stages of cell division is another of the many striking instances in scientific investigation of how conclusions reached theoretically may later be confirmed by direct observation.



WILHELM OSTWALD

A PHOTOGRAPH WHICH FORMERLY HUNG IN THE LABORATORY OF JACQUES LOEB AT THE ROCKEFELLER INSTITUTE. THE ORIGINAL WAS LOANED TO THE SCIENTIFIC MONTHLY BY DR. W. J. V. OSTERHOUT

THE PROGRESS OF SCIENCE

WILHELM OSTWALD

Wilhelm Ostwald, born in September, 1853, at Riga, Latvia, died, in his seventy-eighth year, on April 4 of this year. In him a very brilliant star in the world of science has been extinguished; one might say a star as brilliant as a meteor, if this comparison did not imply a lack of endurance, for this would be the least appropriate attribute to assign him. His characteristics, rather, were steadiness of character, untiring energy in achievement and a strong permanent influence upon the world, not only of science, but also of philosophy. If one asks what was the greatest strength of Ostwald, one might say it was his power of organization, and even this statement, without further comment, may convey a misunderstanding. He not only organized material produced by others and otherwise scattered, but he himself contributed to a considerable extent to the experimental and theoretical data which he so successfully endeavored to organize. His special field of experimental work was in physicochemistry, and this work alone would earn for him a place among the great chemists of his period. It was this work for which, in 1905, he received the Nobel Prize in chemistry.

His first experimental work, which concerned the affinity constants of acids, made it possible to measure the strength of acidity in a quantitative way. His first remarkable achievement in organization was his text-book of general chemistry which was at that time an altogether novel attempt to present chemistry as a science, logically coherent in itself, like physics.

Ostwald studied chemistry and physics at the University at Dorpat, the intellectual center of Livonia, and in general of those Baltic countries which, though outside the borders of the German Reich, were then intellectually dominated by Germans. He became assistant in physics there in 1875, and was appointed professor at Riga in 1881. Here he performed his investigations on the affinity constants of acids, a work early recognized, on the merits of which he received a call to the University of Leipzig in the year 1887. He remained in Leipzig even after resigning from his professorship, living in a suburban home to which he gave the name "Energie," a word very characteristic of him, both with respect to its physical and ordinary meaning. Energy, in the physical meaning of the word, was to him the essential elementary principle, much more real than matter. The energetic point of view in physics and chemistry was to him much more fundamental than the atomistic point of view, so much so that he used the atomistic theory as a mere working hypothesis and was not quite convinced of the real existence of molecules and atoms. The latter view-point, of course, belongs to a period of science which had acquired a rather different aspect due to facts observed and theories established after Ostwald's main period of activity had passed.

The institute created by him at Leipzig became one of the prominent centers of attraction among the German universities, comparable to that of Giessen in Liebig's time. Physicochemistry had become a recognized branch of chemistry mainly due to the centralizing influence of his laboratory at Leipzig. In this period the fundamental laws of what later was called physicochemistry were unfolded by van't Hoff, and a little

later by Arrhenius, and by Nernst, who began his career as one of the first assistants of Ostwald. Ostwald's laboratory was the center of this new branch of science, from where it spread throughout the world. Young chemists from all lands were attracted by his personal influence and through his text-book on general chemistry. He taught these young men that the task of the chemist was not only the preparation and analysis of new compounds, but also the establishment of the physical laws generally underlying chemical reactions. It took quite a time for the older generation of chemists to appreciate the fact that something could be achieved in chemistry, even though no new compound had been prepared. A whole generation of physicochemists has sprung up through the inspiring influence of Ostwald's laboratory. There was in fact in the decades to follow practically no physicochemist in Germany who was not a disciple of Ostwald, and a great many foreign physicochemists originated from or at least sought contact with his laboratory.

His activity at the University of Leipzig lasted fifteen years. The yield in publications of this period is vast, and is deposited in the *Zeitschrift für physikalische Chemie*, founded by Ostwald himself, together with van't Hoff, as the organ of the new branch of science. The first volumes, and I do not mean by this only the first five or ten, may be looked upon to-day as the bible of physicochemistry. Not only did he and his pupils accumulate in this journal a huge amount of material covering experimental work, but scientists the world over used it for their publications. Ostwald availed himself of his journal also for publishing numerous book reviews. The number of books he read and reviewed at this time, always in his invigorating and critical fashion, is almost inconceivable.

It is obvious that a man of such influence was something more than a gifted experimenter in the laboratory. Ostwald was, in addition, a great practical psychologist and knew something of men. He not only discovered facts but also men. In this respect two discoveries should be mentioned which belong among his greatest: The discovery of the American, Willard Gibbs, and of the Swede, Svante Arrhenius. One can not be certain that the work of Willard Gibbs might not have remained buried in the Proceedings of the Academy of Connecticut to the present day if Ostwald had not drawn it into the limelight. He recognized not only the greatness of this American but also the reason why his great work remained practically unknown. Gibbs was in one respect almost the opposite of Ostwald. He lived a retired life, did not aim at a personal influence on men, and deposited his discoveries in such a generalized and abstract way that the chemists of his day could not guess at their real significance. It was Ostwald who gave Gibbs' ideas comprehensible form. Arrhenius' work also might have remained unappreciated or belittled for a long time, had not Ostwald from the very beginning become the enthusiastic partisan of Arrhenius' theory of electrolytic dissociation. It took a long time to convince the chemists of the truth and bearing of this revolutionary theory. The reason why just Ostwald should recognize this so early was not only the ease with which he grasped new ideas in general but the fact that Arrhenius' hypothesis explained in a most simple manner the laws which Ostwald had discovered for the general properties, especially the electric conductivity, of electrolytes. Through Arrhenius' hypothesis it be-

came possible to recognize in Ostwald's so-called law of dilution for electrolytes a particular case of the mass action law established by Guldberg and Waage, and by van't Hoff, and to apply it to electrolytes. Hereby the applicability of one great fundamental law in chemistry, the law of mass action, was found to cover a very much greater field than its discoverers had anticipated. It meant the establishment of a very comprehensive law covering the whole of chemistry which aroused Ostwald's interest in Arrhenius' hypothesis.

His active, keen interest in the work and the personalities of his fellow-scientists, as manifested in his promotion of the work of Gibbs and Arrhenius, was one of Ostwald's outstanding characteristics. He considered everything and anything from the standpoint of its personal and historical development and devoted an unusually large amount of time to historical presentation of the personal lives of the discoverers of the universal laws. He carried this so far that he became what we may call a professional biographer of scientists and even of other great men: so much was he convinced of the inseparability of science and the personal element linking the discoveries and the discoverers. His systematic way of studying even these more psychological things found expression in his book, "Grosse Männer," in which he analyzes the characteristic features of a genius, classifying great men in what he called the classical and romantic types. This trend of his mind caused him to publish the series "Klassiker der exakten Wissenschaften," a collection of reprints of papers old and new, which he considered milestones in science. This collection is missing in scarcely any scientific library to-day.

A common thought permeates his studies on the development of a genius. It is a discontent with the educational system of the "humanistic Gymnasium" in Germany as conducted at that time, in which the study of Latin and Greek exclusively was utilized for the training of the mind, and natural science was scorned. It is not easy to imagine at the present time and in this country how much courage was requisite for such a combat against the well-established and standardized educational system. He himself was certainly not a good student in his Gymnasium days. This was not because he was not gifted but because he was too much distracted from his school work by diverse interests. His mind was occupied with practical engineering problems, experiments in the field of the natural sciences and collecting in a more biological field. When he graduated from the Gymnasium and entered the university he was greatly distracted from the regular curriculum by a thorough enjoyment of the hilarious student life characteristic of German universities. When, after paternal admonition, he took to earnest study, he surprised every one by reaching his graduation in an unbelievably short time. All his life he fought for a renovation of the educational system and in spite of great reluctance a change has taken place in the direction suggested by him.

He retired at a comparatively early age from his professorship, in conformity with a principle which he always emphasized in his biographical studies, namely, that all great achievements of a genius are merely elaborations of ideas acquired in youth and that no new fundamental idea is originated in later life. He believed that physicochemistry might be more fruitful of progress if another generation were allowed to unfold it. On the other hand, he had gathered from his youth such a rich collection of ideas

outside physicochemistry that he decided to elaborate these rather than to follow the course of physicochemistry which gradually began to turn in new directions.

Among the subjects which he pursued after his retirement, two may be mentioned, one of a philosophical or rather theological nature, the other lying on the border-line of physics and art. The first of these two is the cause of monism. Jointly with Ernst Haeckel, the zoologist and propagator of Darwin's ideas, he worked for the cause of monism. He published the pamphlet, "Christendom as Forerunner of Monism" and the series of "Monistische Sonntags-Predigten." Not only in his chemistry and physics but also in his theories on psychological behavior, even to the point of religious ideas, the concept of energy plays a central part.

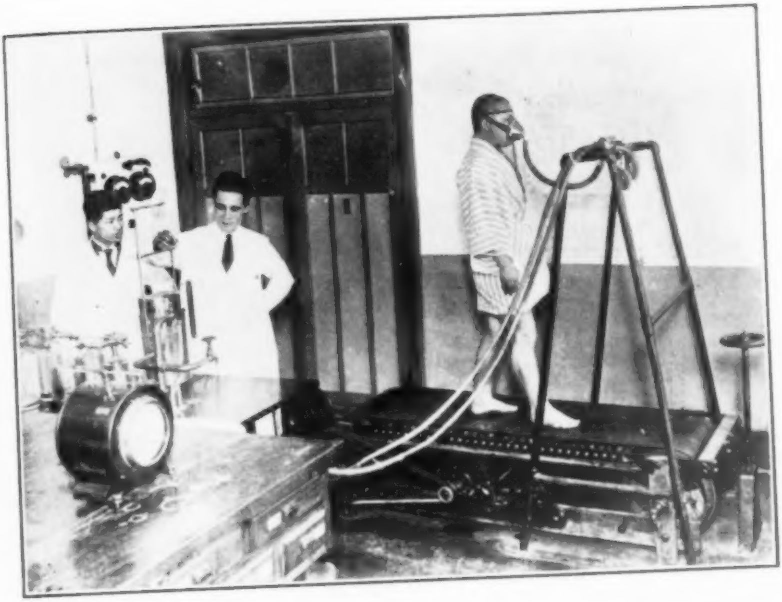
The other subject which occupied his mind in later life was a theory of colors. Painting had been a favorite and successful occupation of his. Even to this he tried to apply a scientific method for the demonstration of the problem of color harmony. His occupation in this field led him to develop a color system which aims at describing any shade of color by attributing to it three properties, each measurable in a quantitative way. Each color is supposed to be composed of a certain quantity of black, white and color proper. Although the physical basis of the theory has not been unanimously accepted, yet the practical result of the establishment of a color system by which it is possible to reproduce every shade of color by three attributes, has been recognized as a practical solution of the problem.

Another favorite subject of Ostwald's was Esperanto, the artificial international language, and he was much interested in encouraging its more widespread use. He also realized the importance of, and worked toward the standardization of publications with respect to size, printing type, binding, international standard coin and so forth, for the sake of simplicity, systematic order and clearness.

If one were to choose which of Ostwald's scientific achievements may be considered most outstanding, the work selected would vary according to the sphere of interest of the chooser. The author of this review would emphasize the work on the definition and measurement of strength of acidity; his work on catalysis, especially the catalytic oxidation of ammonia to nitric acid and the elaboration of the theory of catalysis beyond the point to which it was brought by its originator, Berzelius; and the first development of those ideas on selective permeability of membranes for various ions which is still the subject of many experimental studies and which may ultimately lead to an understanding of the electric phenomena in living organisms.

The significance of a man like Ostwald, however, is by no means exhausted by an enumeration of his scientific achievements. He was a great personality and a fighter in the cause of logic, reason, justice, honesty, peace and humanity.

LEONOR MICHAELIS



SCIENCE IN JAPAN

ABOVE IS SHOWN DR. TAKHIRA, IN CHARGE OF THE KOISHIKAWA NUTRITION LABORATORY IN TOKIO, WHO IS CARRYING ON RESEARCHES ON METABOLISM. BELOW, A JAPANESE STUDENT IS HAVING A PSYCHOLOGICAL TEST AT THE KOISHIKAWA OFFICE IN TOKIO

THE BOYDEN STATION OF HARVARD COLLEGE OBSERVATORY IN SOUTH AFRICA

FORTY-ONE years ago, in 1891, a generous fund left by Uriah Atherton Boyden, a mechanical engineer of Boston, enabled Harvard College Observatory to fill a need of fundamental importance and to establish, two miles north of the capital of Southern Peru—Arequipa—on the western slopes of the Andes and at an elevation of 8,050 feet, its southern branch, known as the "Boyden Station."

From the purely astronomical standpoint, Arequipa was not an ideal place for an astronomical observatory, due to a practically continuous spell of cloudy weather lasting from November to March or April. However, the choice of a suitable site in southern latitudes was at that time very limited indeed. Communication between the United States and the continents of the southern hemisphere was hardly developed, and living and sanitary conditions left much to be desired, disregarding even the dangers from frequent revolts and political uprisings which seem to be endemic in many of the southern republics.

Arequipa was always considered a temporary site and, as early as 1908, the late Professor Bailey came to South Africa to study the prevailing atmospheric conditions and to look for a permanent site.

Bailey's investigations brought to light the superior qualities of the South African high plateau ("high veld") but the financial status of Harvard Observatory in 1908 and subsequent years did not permit of the heavy expense involved in the transfer of the Boyden

THE TURRET AND THE UNDERGROUND BUILDING

FOR THE 60-INCH REFLECTING TELESCOPE AT HARVARD KOPJE. (PHOTOGRAPHED IN NOVEMBER, 1931)

THE BRUCE 24-INCH REFRACTOR

Station from South America to South Africa. The great war and the death of the director of Harvard Observatory, Professor E. C. Pickering, with the ensuing unsettled period of practically three years during which Professor Bailey was acting director, postponed matters indefinitely.

The appointment in 1921 of Dr. Harlow Shapley as director of Harvard Observatory marked the final phase in settling the question of the Boyden Station.

As it was thought that suitable sites could be found in South America, and the heavy expenses of moving from one continent to another could be obviated, the writer, at Professor Shapley's request, undertook three expeditions between the years 1923 and 1926 in the high plateaus of Northern Chile (elevation 9,500 feet) and the pampas of Southern Peru, testing sites and studying atmospheric conditions. At the same time, data concerning the prevailing sky conditions in several parts of Australia were kindly submitted by the authorities there for perusal.

The results thus obtained showed that the balance of arguments was greatly in favor of the South African high veld, which was therefore selected as the permanent home for the Boyden Station. Generous gifts from the International Education Board and from Harvard University enabled Dr. Shapley to take his final steps. Late in 1926 the Boyden Station at Arequipa was dismantled and in 1927 the instruments, library, etc., were shipped to South Africa *via* New York. The writer arrived in South Africa in July, 1927, and work for finding the best site and establishing the Observatory started at once.

The interest shown by the South African people in the establishing of the Boyden Station is worthy of high praise, and the first months of my stay in this country were filled with continuous delightful surprises.

After a careful examination of localities and conditions, Mazelspoort was

finally selected as the site for the station. The site—a low hill rising about 200 feet above the surrounding veld, which is itself 4,500 feet above sea-level—is situated ENE and at a distance of 15 miles from the town of Bloemfontein, the capital of the Orange Free State, and is to-day officially known as "Harvard Kopje" (kopje being the South African word for hill). The grounds, about 14 acres, were generously presented to the observatory by the municipality of Bloemfontein, which also constructed the road leading to the top of the hill, installed water and power mains together with fire protection, and gave the services of the city's engineer and staff, all free of charge.

To-day, there are five photographic telescopes in continuous operation, their apertures ranging from 3 inches up to 24 inches. In addition there is a transit instrument, mainly for the determination of time.

In July, 1931, work was started for the erection of the building (semi-pit type) and of the turret to house a reflecting telescope of 60-inch aperture, and it is hoped that this instrument will be in operation about the middle of the current year.

The work carried on at the Boyden Station, which, with the equipment at its command and the unlimited field of the southern sky for exploration, constitutes one of the main arteries of Harvard Observatory, is purely photographic. The program, outlined by Director Shapley, bears on the structure of our Galaxy, the extragalactic objects, the Super-Galaxies and the Metagalaxy, and will necessitate many years of continuous but pleasant work both at the telescope and in the office.

It is very gratifying to state that the results reached so far are very promising indeed and highly encouraging.

J. S. Paraskevopoulos

Harvard Kopje,
South Africa,
February 6, 1932

THE U. S. FOREST PRODUCTS LABORATORY

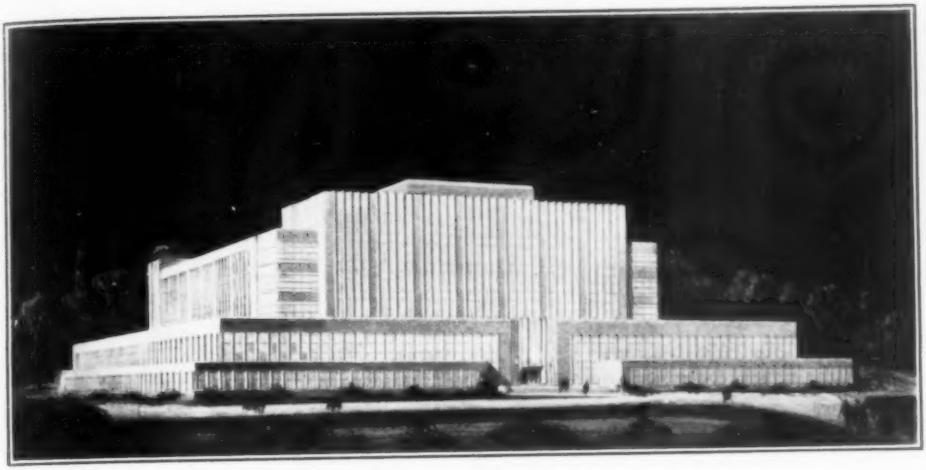
Work is well advanced on a new building for the U. S. Forest Products Laboratory, at Madison, Wisconsin, which has been under construction since August.

The Forest Products Laboratory is devoted to the better understanding of the properties of forest materials and to broadening the fields of use for forest products. In its six stories, with total floor space of 175,000 square feet, the new building will contain modern facilities for investigating and testing wood and other forest products with respect both to their fundamental properties and their many uses.

A large group of dry kilns equipped for close control of temperature, humidity and air circulation will help to solve the problems of seasoning many species and types of wood. A cold storage chamber will be provided in which green logs and timber can be kept in unchanged condition for experimental work at any time.

Since every step of wood manufacture and construction and the satisfactory performance of wood in service are influenced by moisture conditions, a number of humidity rooms will be provided in which wood can be brought to the exact moisture content desired for study under conditions simulating any season of the year or any climate of the temperate zone.

Machines for testing timbers and framework up to a breaking load of 1,000,000 pounds will be available in a testing gallery accommodating pieces and panels as large as 30 feet high and



THE U. S. FOREST PRODUCTS LABORATORY

100 feet long. Tests of boxes and shipping crates can be carried on at any degree of dryness or dampness that would be met in service by storing and testing the containers in a special moisture-control room served by movable machinery.

The pulp and paper research laboratory, occupying six floors at one end of the building, will include grinder equipment, a digester tower 40 feet square, beating and refining apparatus and an experimental paper machine, with all moving parts under precision control. With this equipment the study of various American woods as pulp and paper raw material will be continued, along lines that have already broadened the pulpwood market and pointed the way to improved chemical pulping.

Among unusual features of the building will be an ultra-violet ray chamber, where wood can be sterilized for mycological studies and where paints and other materials can be exposed for test, an x-ray room providing for the examination of the minute structure and growth characteristics of wood, a microphotographic studio and a stone table and shaft for ultracentrifuge apparatus to determine molecular sizes of cellulose and other wood components.

Provision is made for a large timber preservation laboratory, a wood fermentation unit, fractionating stills, a general section of wood chemistry, wood gluing, painting, finishing and fireproofing laboratories, and facilities for the study of wood fungi and insect pests and the abatement of their damages.

The Forest Products Laboratory is part of the Forest Service of the U. S. Department of Agriculture, which administers the country's greatest reserve of timber, the national forests. "Forestry is concerned not only with timber growing, but also with the efficient use and profitable marketing of forest crops," said Carlile P. Winslow, director of the laboratory, in explaining the purposes of the new building.

"Success in the economic restoration of idle forest and submarginal agricultural lands demands the development of new uses for wood to replace those captured by other materials, the modernizing of existing wood uses and the adaptation of wood to complex and changing requirements. The laboratory will increasingly contribute to these ends through the improved facilities for phys-

ical, mechanical, chemical and biological research on wood and other forest products which the new building will afford. The work carried on for several years past by the staff of nearly 200 has taxed available facilities, and since Congress has already authorized the doubling of the annual operating appropriation, the need for new and larger quarters is imperative."

Since the Forest Products Laboratory was opened by the U. S. Department of Agriculture, in 1910, it has occupied buildings owned by the University of Wisconsin. The assistance is based on the original cooperative arrangement whereby the laboratory is available to the university faculty and advanced students for research, and its staff gives lectures in the university on wood chemistry and technology and other subjects related to forest utilization.

The university board of regents has aided the new building project by donating a choice site of 10 acres overlooking Lake Mendota and the university campus.

In general plan the new building will be U-shaped, about 275 feet in length and over-all breadth. It is of modern design, emphasizing "stepped-back" construction, vertical lines and large areas of glass in the external walls. By terms of the Congressional authorization act, the building will be of fireproof construction throughout.

DR. VANNEVAR BUSH

(LEFT) WHO HAS RECENTLY BEEN APPOINTED VICE-PRESIDENT OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY AND DEAN OF ITS SCHOOL OF ENGINEERING. DR. BUSH HAS BEEN PROFESSOR OF ELECTRICAL POWER TRANSMISSION AT THE INSTITUTE SINCE 1923. PRESIDENT KARL T. COMPTON IS SEATED AT THE RIGHT

INDEX

NAMES OF CONTRIBUTORS ARE PRINTED IN SMALL CAPITALS

Abel, John J., Portrait, 182
Agassiz Medal Award to Dr. Bigelow, 377
American Association for the Advancement of Science, New Orleans Meeting, 85, 187; President of the, 183
Amphibian in Art and Literature, S. W. FROST, 369
ANDERSON, E., Cyclones, 351
ANDREWS, E. A., An Ant Hill, 97
Animal Grafting, H. H. COLLINS, 261
Ant Hill, E. A. ANDREWS, 97
Ants, Field Study of, W. M. WHEELER, 397
Apollo's Sacred White Mice, C. E. KEELER, 48
Appalachian Trail, B. MACKAYE, 330
Atom, Breakdown of the, A. GOETZ, 125; Weighing the, 481

Battelle Memorial Institute, 475
Beauty and the Science Beast, J. O. PERRINE, 465
BENEDICT, F. G., Reptiles and Human Physiology, 420
BENSON, H. K., Cellulose in Industry, 454
Bergius, Friedrich, Portrait, 280
Bird Migration, A. WETMORE, 459
Birth Control, S. J. HOLMES, 247
Blow-fly Larvae, E. F. ROBERTS, 531
Boas, Franz, Portrait, 84
Bosch, Carl, Portrait, 278
Browne, C. A., Portrait, 86
BUNKER, F. F., "Genes," 556

Caduceus, S. L. TYSON, 492
CALDWELL, M. G., and J. CALHOUN, Culture of the Campas Indians of South America, 238
CALDWELL, R. G., American Panics, 298
Calendar, Simplifying the, C. F. MARVIN, 366; E. B. DELABARRE, 537
Campas Indians of South America, Culture of, M. G. CALDWELL and J. CALHOUN, 238
CANNAN, E., Population, 1831–1931, 147
Cannibalism among the Sharks and Rays, E. W. GUDGER, 403
Cannon, A. J., Award, 379; Portrait, 378
Cause or Chance, P. R. HEYL, 273
Cellulose in Industry, H. K. BENSON, 454
Century, Nuclear, L. W. SHARP, 322
Child Study, A. GESELL, 265
CLARK, A. H., Science and the Radio, 268; The Stars on Our Flag, 469
COLLINS, H. H., Animal Grafting, 261
Continental Shelf, G. T. RUDE, 547
COWLES, H. C., The Ever-changing Landscape, 457
Crops and Civilizations, E. D. MERRILL, 362
Cruelty, Prevention of, M. C. HALL, 211
Cyclones, E. ANDERSON, 351

DARWIN, C. G., Uncertainty Principle, 387
DAVENPORT, C. B., Heredity and Disease, 167
Davis, Bergen, Portrait, 86
DELABARRE, E. B., Simplified Calendar, 537
DENTON, F. M., Why Wave Mechanics?, 195
Depressions and Democracy, W. B. MUNRO, 291
DESCH, C. H., Metals in the Use of Man, 550
DICKINSON, H. C., Liquid Helium, 75
Dinwiddie, A. B., Portrait, 90

Eastman, George, Portrait, 474
Elliott, D. S., Portrait, 90
Erosion, C. L. FORSLING, 311

Flag, The Stars on Our, A. H. CLARK, 469
FLEMING, J. A., The Earth's Magnetic Field, 499
FORSLING, C. L., Erosion, 311
FRASER-HARRIS, D. F., Biology in Shakespeare, 54
von Frey, Max, Portrait, 478; 479
FROST, S. W., The Amphibian in Art and Literature, 369

Gamma-Rays, LORD RUTHERFORD, 483
Geology and Oceanography, W. H. TWENHOFEL, 429
GESELL, A., Child Study, 265
GOETZ, A., The Breakdown of the Atom, 125
Greely, A. W., Portrait, 376
Gregory, William K., Portrait, 87
GUDGER, E. W., Cannibalism among the Sharks and Rays, 403

HALL, M. C., The Prevention of Cruelty, 211
HARDING, T. S., The Metamorphosis of the Horse Doctor, 446
HARRAR, N. J., Washington Sets a River on Fire, 353
Harvard College Observatory, Boyden Station of, in South Africa, 572
Health, Public, and Medicine, C. W. MCCOY, 356
Hedrick, E. R., Portrait, 86
Hegner, Robert, Portrait, 87
Helium, Liquid, H. C. DICKINSON, 75
Heredity, and Disease, C. B. DAVENPORT, 167; and Environment, A. S. PEARSE, 541; the Units of, F. F. BUNKER, 556
HEYL, P. R., Cause or Chance?, 273
HOLMES, S. J., Birth Control, 247
HOPKINS, B. S., Nature's Puzzles, 172
Horn, Ernest, Portrait, 90
Horse Doctor, Metamorphosis of, T. S. HARDING, 446
Human Variations, A. H. SCHULTZ, 360

Ice Manufacture, D. B. KEYES, 176
Indians, Plains, Marriage and Family Life among, R. H. LOWIE, 462
"Instinct" and "Instinctive," R. S. UHRBROCK, 544

JEANS, J. H., Beyond the Milky Way, 35
Johnson, Douglas, Portrait, 87

Karsner, T. Howard, Portrait, 88
KEELER, C. E., Apollo's Sacred White Mice, 48

KEYES, D. B., Ice Manufacture, 176
Kimball, Dexter S., Portrait, 88

Landscape, Ever-changing, H. C. COWLES, 457
Langfeld, Herbert S., Portrait, 88
LAUFER, B., Sino-American Contacts, 243
LEIGHTON, M. M., Prehistoric Men, 77
Life, The Unity of, C. E. MCCLUNG, 259
LINDSAY, R. B., Point of View in Physics, 115
Lowell, Percival, Portrait, 6
LOWIE, R. H., Marriage and Family Life among the Plains Indians, 462
LUKENS, R. R., Oddities of the Ocean, 552

MCCLUNG, C. E., The Unity of Life, 259
MCCOY, G. W., Medicine and Public Health, 356
MACKAYE, B., The Appalachian Trail, 330
Magnetic Field, Earth's, J. A. FLEMING, 499
Marsh, Othniel Charles, Centenary of, 95; Portrait, 94
MARVIN, C. F., Simplifying Our Calendar, 366
Massachusetts Institute of Technology, New Research Laboratories, 473
MERRILL, E. D., Crops and Civilizations, 362
Merrill, E. D., Portrait, 87
Metals, Nature of, E. E. SCHUMACHER, 22; in the Use of Man, C. H. DESCH, 550
Milky Way, Beyond the, J. H. JEANS, 35
MILLER, D. C., The Pipes of Pan, 73
Moore, J. H., Portrait, 86
MUNRO, W. B., Democracy and Depressions, 291
Munro, William B., Portrait, 88

NEWMAN, H. H., Identical Twins, 169
Nobel Prize in Chemistry, 279

Ocean, Oddities of the, R. R. LUKENS, 552
Oceanographic Chemistry, T. G. THOMPSON and E. G. MOBERG, 442
Oceanography of the Pacific, T. W. VAUGHAN, 128
Ostwald, Wilhelm, Portrait, 566; 567

Pan, the Pipes of, D. C. MILLER, 73
Panics, American, R. G. CALDWELL, 298
PEARSE, A. S., Environment and Heredity, 541
Perfumes and Cosmetics, G. M. ZIEGLER, 222
PERRINE, J. O., Beauty and the Science Beast, 465
Physics, R. B. LINDSAY, 115; American Institute of, 287
Pigments, Lead, A. H. SABIN, 31
PINKUS, L. F., A Spider Caught A Snake, 80
Pluto, R. L. PUTNAM and V. M. SLIPHER, 5
Population, 1831–1931, E. CANNAN, 147
Prehistoric Men in the Middle West, M. M. LEIGHTON, 77
Primates, Mentality of, L. A. WHITE, 69
Progress of Science, 85, 183, 279, 377, 473, 566
Pupin, M. I., Portrait, 288
PUTNAM, R. L. and V. M. SLIPHER, Pluto, 5
Puzzles, Nature's, B. S. HOPKINS, 172

Radio and Science, A. H. CLARK, 268
Relativity Theory, M. TALMEY, 41
Reptiles and Human Physiology, F. G. BENEDICT, 420
Rice, E. W., Jr., Portrait, 288
ROBERTS, E. F., Blow-fly Larvae, 531
ROBINSON, L. V., Variable Stars, 343
Rubber from Rocks, 385
RUDE, G. T., The Continental Shelf, 547
RUSSELL, H. N., The Spectroscope, 487
RUTHERFORD, LORD, The Gamma-Rays, 483

SABIN, A. H., Less Well-known Lead Pigments, 31
SCHULTZ, A. H., Human Variations, 360
SCHUMACHER, E. E., The Nature of Metals, 22
Science Service Radio Talks, 73, 167, 259, 356, 454, 547
Shakespeare, Biology in, D. F. FRASER-HARRIS, 54
SHARP, L. W., A Nuclear Century, 322
Sino-American Contacts, B. LAUFER, 243
Social Psychology and Reform, K. YOUNG, 252
Spectroscope, H. N. RUSSELL, 487
Spider and a Snake, L. F. PINKUS, 80
Stars, Variable, L. V. ROBINSON, 343
Switzerland, Water Power in, 381

TALMEY, M., The Relativity Theory, 41
THOMPSON, T. G., and E. G. MOBERG, Oceanographic Chemistry, 442
Thumb, Tom, Three Hundred Years of, H. B. WEISS, 157
TWENHOFEL, W. H., Relation of Geology to Oceanography, 429
Twins, Identical, H. H. NEWMAN, 169
TYSON, S. L., The Caduceus, 492

UHRBROCK, R. S., Popular Usage of the Terms "Instinct" and "Instinctive," 544
Uncertainty Principle, C. G. DARWIN, 387
U. S. Forest Products Laboratory, 574

VAUGHAN, T. W., Oceanography of the Pacific, 128

Warburg, Otto, and the Nobel Prize, 283; Portrait, 284
Ward, Robert DeCourcy, 192; Portrait, 193
Washington Sets a River on Fire, N. J. HARRAR, 353
Wave Mechanics, F. M. DENTON, 195
WEISS, H. B., Tom Thumb, 157
WETMORE, A., Bird Migration, 459
WHEELER, W. M., Field Study of Ants, 397
WHITE, L. A., Mentality of Primates, 69
Williams, C. G., Portrait, 90

YOUNG, K., Social Psychology, 252

ZIEGLER, G. M., Perfumes and Cosmetics, 222

Now In Press

A Complete, Copiously Illustrated

Catalogue

of Present and Forthcoming Publications

of

Medical Life Press

Send For a Free Copy

LAY READERS with a scientific bent and all progressive scientists who take interest in the cultural background of the medical profession will find in this catalogue valuable information of the Medical Life Press' publications in medical history and biography. The catalogue lists works by a number of outstanding medical historians, including the dominating figure of them all, Sudhoff of Vienna. The numerous illustrations enliven the descriptive material and serve to make the catalogue additionally valuable.

A copy is yours for the asking. Please use the coupon below.

Medical Life Press
12 Mount Morris Park West,
New York, N. Y.

Medical Life Press,
12 Mt. Morris Park W., N. Y.

$\frac{6}{100000}$ $\frac{3}{50,000}$ cm.

Gentlemen:

λ max = $\frac{3}{50,000,000}$ cm.

Please send me gratis, as per your announcement in THE SCIENTIFIC MONTHLY, a copy of your **Catalogue of Publications.**

Name ....

Address ....

City .... State ....

Vol. XXXIV, No. 6 JUNE, 1932 Whole No. 201

The Scientific Monthly

An Illustrated Magazine Devoted to the Diffusion of Science

J. McKEEN CATTELL, Editor

WARE CATTELL, Associate Editor

Published by THE SCIENCE PRESS

LANCASTER, PA.—NEW YORK, N. Y., Grand Central Terminal—GARRISON, N. Y.

Single Number, 50 cents **Yearly Subscription, $5.00**

Entered as second-class matter at the post office at Lancaster, Pa., July 18, 1923, under the Act of March 3, 1879.

RECENT BOOKS OF SCIENTIFIC INTEREST

The Development of Physiological Chemistry in the United States. RUSSELL H. CHITTENDEN. 427 pp. $4.50. Chemical Catalog Company.

The purpose of this book is to show something of the growth and development of physiological chemistry in this country during the past half century. The volume is one in the American Chemical Society Monograph Series.

Can Science Explain Life? (1931 edition with 1932 supplement.) CARL F. KRAFFT. 98 pp. $1.00. Box 1421, Wash., D. C.

The author's spirazine theory, which he believes furnishes a satisfactory mechanistic explanation for heredity, has been combined with a new electrical theory in an effort to explain purposiveness.

The Story of Medicine. VICTOR ROBINSON. xii + 527 pp. $5.00. Albert & Charles Boni.

The bulk of this volume deals with the progress of scientific medicine, but space is also devoted to magic, superstition, "quackery" and mesmerism. In tracing the history of medicine from the time of the medicine man to the modern physician, the author devotes much space to the men who have been responsible for the development of the medical sciences.

Whaling in the Antarctic. A. G. BENNETT. x + 222 pp. Illustrated. $3.00. Henry Holt & Company.

A book on the modern whaling industry, telling of the methods of capturing whales, their environment and about the whales themselves. The first chapter is devoted to "old-time" whaling. The author spent four years with whaling fleets.

Tucson, The Old Pueblo. FRANK C. LOCKWOOD and DONALD W. PAGE. 94 pp. Illustrated. $1.50. Frank C. Lockwood.

The authors have traced back to its sources the history of Tucson. Dr. Lockwood was professor of English and dean of the college of letters, arts and sciences at the University of Arizona.

Seventy Years in Archaeology. SIR FLINDERS PETRIE. 307 pp. Illustrated. $4.00. Henry Holt and Company.

A record of the life work of one of the world's foremost archeologists. The reader is led through the Mediterranean basin to the pyramids of Gizeh as the author delves into the secrets of antiquity.

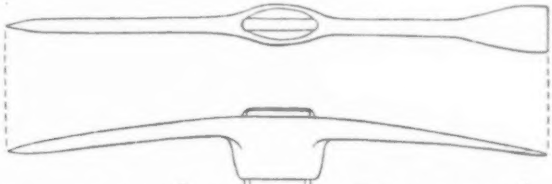
The Laws of Human Nature. RAYMOND H. WHEELER. xiv + 235 pp. $2.00. D. Appleton and Company.

A simplified and condensed presentation of the Gestalt movement in psychology, which explains the basic principles and concepts that are modifying our interpretation of mind and behavior. Similar movements in other sciences are compared.

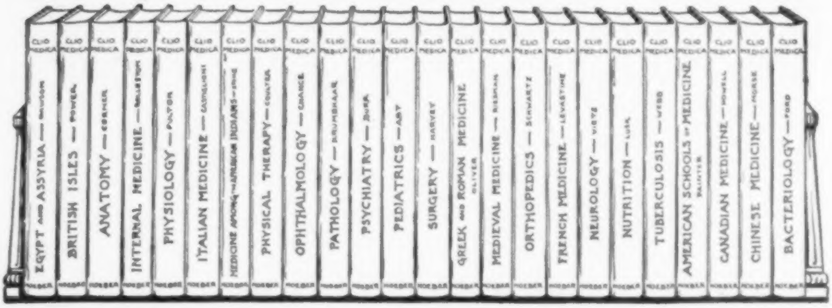
Rambling through Science. A. L. DE LEEUW. 320 pp. Illustrated. $2.50. Whittlesey House.

A series of "ramblings" through science, consisting of familiar talks about sound, light, ether, relativity, the fourth dimension, the elements, etc., as well as an account of how many important scientific discoveries have been made.

Books previously announced will be given space six times on this page for $12.00



CLIO MEDICA



A Series of Primers on the History of Medicine

Edited by E. B. KRUMBHAAR

"THIS series of primers, which presents a concise and readable history of medicine, has been designed upon lines unique in the fact that each booklet discusses a particular phase of medical history in its entirety and yet remains of pocket size."—*Journal of Iowa State Medical Society*

PUBLISHED TO DATE

THE BEGINNINGS: EGYPT & ASSYRIA
WARREN R. DAWSON
12mo, cloth, 86 pages . . $1.50 *net*

MEDICINE IN THE BRITISH ISLES
SIR D'ARCY POWER
12mo, cloth, 94 pages . . . $1.50 *net*

PHYSIOLOGY
JOHN F. FULTON
12mo, cloth, 157 pages, 7 illus. $1.50 *net*

ANATOMY
GEORGE W. CORNER
12mo, cloth, 97 pages . . $1.50 *net*

INTERNAL MEDICINE
SIR HUMPHRY ROLLESTON
12mo, cloth, 95 pages . . . $1.50 *net*

ITALIAN MEDICINE
ARTURO CASTIGLIONI
12mo, cloth, 100 pages, illus. $1.50 *net*

IN PRESS

MEDICINE AMONG THE AMERICAN INDIANS. By ERIC STONE

PHYSICAL THERAPY
By JOHN S. COULTER

IN PREPARATION

DERMATOLOGY
By W. A. PUSEY

MEDIEVAL MEDICINE
By DAVID RIESMAN

PATHOLOGY
By E. B. KRUMBHAAR

OPHTHALMOLOGY
By BURTON S. CHANCE

GREEK & ROMAN MEDICINE
By JOHN R. OLIVER

BACTERIOLOGY
By WILLIAM W. FORD

GERMAN MEDICINE
By WILLIAM HABERLING

SURGERY
By SAMUEL C. HARVEY

ORTHOPEDICS
By R. PLATO SCHWARTZ

FRENCH MEDICINE
By LAIGNEL LEVASTINE

NEUROLOGY
By HENRY VIETS

AMERICAN SCHOOLS OF MEDICINE
By C. F. PAINTER

CANADA
By WILLIAM B. HOWELL

CHINESE MEDICINE
By W. R. MORSE

PSYCHIATRY
By CHARLES W. BURR

PEDIATRICS
By ISAAC A. ABT

NUTRITION
By GRAHAM LUSK

TUBERCULOSIS
By GERALD WEBB

Other Volumes to be Announced. Each Volume Complete in Itself and Sold Separately

PAUL B. HOEBER, INC · PUBLISHERS · 76 FIFTH AVE · N.Y.
Publishers of *The American Journal of Surgery; Annals of Medical History; Annals of Roentgenology*, etc.

TS

y

y
sity

tics
eral
in
ural
its
nen-
nda-
It
ork,
lear
ore,
the
tics.
e of
ac-
e of
the
ects,
as-

ext-
gan-
be-

NY